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ASSESSMENT OF WOOD RAW MATERIALS AND WOOD UTILIZATION POTENTIAL FOR THE LODGEPOLE PINE AND SPRUCE-FIR TYPES IN COLORADO AND WYOMING

FINAL REPORT

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RM Cooperative Research Agreement 16-927-CA

CSU Project No. 2243

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Department of Forest and Wood Sciences

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ABSTRACT OF THESIS

ASSESSMENT OF WOOD RAW MATERIALS AND WOOD UTILIZATION POTENTIAL FOR THE LODGEPOLE PINE AND SPRUCE-FIR TYPES IN COLORADO AND WYOMING

The Colorado and Wyoming region is experiencing a bark beetle epidemic in the lodgepole pine stands. A past epidemic in the spruce stands has left many acres of dead timber. Removal of this dead and dying material and thinning to prescribed stocking levels are necessary to restore the vigor to the stands. Markets recognizing the intrinsic value of the material must be found so that the best silvicultural practices can be exercised. The technical feasibility of this material for traditional and potential products was determined. For comparative purposes both live and beetle-killed lodgepole pine 2 x 4's were studied from Star Studs Inc., Afton, Wyoming. Lodgepole pine thinning which ranged from 5 to 7 inches in DBH were harvested and also included in the study. Live and beetle-killed Engelmann spruce were compared also. This material was obtained from Kaibab Industries, Eagle, Colorado. The spruce-fir thinnings were harvested near Eagle Colorado and transported to Fort Collins for manufacture into 2 x 4 test material. As a basis for comparison various physical and chemical tests were conducted to determine the integrity and usefulness of the dead and thinning material with the material cut from living trees. Analyses of variance tests were conducted for the different material classes. The test results

were then combined into groups that were considered the most important properties for a given product. Finally all results were expressed as a percentage of the live lodgepole standard. The summary of these properties produced an index value for each of the material classes for the various products considered.

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August, 1979

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CHAPTER I

INTRODUCTION

The lodgepole pine type encompasses more than 1,138,000 acres of commercial forest land in Colorado and more than 1,200,000 acres in Wyoming. The spruce-fir timber type covers about 536,000 acres of commercial forest land in Wyoming and more than 1,640,000 acres in Colorado. These two timber types account for 42 percent of the commercial forest land in Colorado and 54 percent of the commercial forest land in Wyoming (Smego et al. 1978).

The U. S. Forest Service, Colorado State Forest Service and Wyoming State Forestry Division have stated a real need to assess the possible utilization and marketing opportunities for wood raw materials from these forest types. Fundamentally, these raw materials consist of timber and timber by-products that would be generated by timber management programs developed to meet multiple-use management objectives. Included in this raw material are large amounts of dead and dying timber. Stands with as much as 17 M board feet per acre gross volume of dead Engelmann spruce exist on the White River, Arapahoe, and Routt National Forests in Colorado. This dead timber resulted from a spruce bark beetle, *Dendroctonus rufipennis*, epidemic that occurred in the late 1940's and early 1950's (Bennett, 1978). In addition to this, the mountain pine beetle, *Dendroctonus ponderosae*, is causing serious losses in the lodgepole pine stands, particularly in western Wyoming.

In recent years it has been estimated that more than 200,000 acres of lodgepole pine are infested with the mountain pine beetle in Colorado and Wyoming (Roe and Amman, 1970; Alexander, 1972, 1974).

The silvicultural prescription to control these insect attacks includes the removal of susceptible trees, infested trees, and green cull material, or partial cutting or thinning. Overmature and overstocked stands are more susceptible to insect attacks, therefore, thinning the stands will make the remaining trees more vigorous and resistant to insect infestations in the future.

The results of these silvicultural practices would be large volumes of wood raw materials being removed from the forests. Markets must be available to utilize the wood raw material to make the silvicultural practices acceptable and economically feasible. Every end use of wood entails a unique group of raw material requirements essential or at least desirable for successful processing and product performance. It is the purpose of this research to determine the suitability of various classes of raw materials for conversion to products, both old and new, at existing facilities or at facilities to be installed for this purpose.

CHAPTER II

REVIEW OF LITERATURE

According to a 1975 Forest Service report, an amount of timber equal to 25 percent of the annual cut is lost each year to fire, insects and disease (USFS Forest Resources Report No. 21). An additional undetermined amount is lost due to retarded growth. This timber has accumulated until currently there are billions of board feet of standing dead timber in the western United States. The yearly salvage, however, consistently represents less than 10 percent of the annual mortality (Snellgrove and Fahey, 1978). Dead timber can be observed from two viewpoints. Negatively, it can create a management problem for the forester. Positively, it can be an opportunity to extend the timber resource. The possibilities for utilizing this resource include:

pulp
composition boards
fuelwood
solid wood products

This chapter, through a review of the literature, summarizes existing knowledge on the utilization of dead timber.

Background of the Problem

The mountain pine beetle and the spruce beetle attack the phloem layer of the tree. The adult beetle uses the phloem as a food source and also constructs an egg gallery there. The beetle larvae feed at

right angles to the egg gallery and girdle the tree causing its death (Roe and Amman, 1970). The bark beetle attacks the least vigorous element of the stand. This includes the overmature and the suppressed trees of the stand.

Following the insect attack, the tree is infected by a fungus stain. This blue-stain or sap-stain results either from the dark color of the fungus hyphae, or by the diffusible pigments produced by them (Levi and Dietrich, 1976). The stain is limited to the sapwood of the tree. The hyphae of the blue-stain fungus grow primarily in the rays. The movement between cells is essentially through the pits. Blue-stain fungi derive their nourishment mainly from the soluble and semisoluble materials contained in the wood cells and the wood rays and from the wood rays themselves (Scheffer, 1973). The result is that their effect is mainly one of discoloration which causes a loss of the tree's economic value due to a loss marketability which is caused by buyer prejudice.

The degradation of the ray parenchyma cell walls and the openings in the microstructure made by the penetrating fungus make blue stained wood more permeable than "bright" wood. This makes the blue stained wood more vulnerable to decay (Scheffer and Lindgren, 1970).

This along with the fact that at the present time the best way to control the insect epidemics is to remove the infested trees and thin the stands to yield a more vigorous stand (Row and Amman, 1970) should be the incentive for the earliest removal possible of beetle-infested trees.

Pulp

The effect of dead wood on the quality and quantity of pulp can be divided into two categories: the effect of blue-stain on the quality of the pulp and the effect of moisture content on pulp yields. Levi and Dietrich (1978) state that the effect of blue-stain on the quality of pulp has been studied by several researchers. Each study came to the same general conclusions. The major effect of the blue stain was one of discoloration or darkening of the pulp produced by both mechanical sulphite or sulphate pulping. The blue stain had no significant effect on the yield or strength of the pulp produced. The blue stain discoloration of the infected wood did require more bleaching to prepare the pulp. The amount of increased bleach was dependent on: The intensity of the blue-stain in the wood, percentage of blue-stained wood used and the degree of whiteness desired. In Levi and Dietrich (1978) Chidester stated that bleaching a 95 percent blue-stained sulphate pulp required 2.5 to 5 percent more standard bleaching powder than unstained pulp.

The effect of moisture content in kraft pulping was studied by Nolan (1959). He came to the following conclusions: 1) air-dry chips, in kraft pulping, will cook at the same rate as moist chips but are lower in maximum screened yield by 3.0 to 4.0 percent, 2) dry chips can be impregnated with water, returning them to such a condition that they will respond to kraft pulping in a manner similar [sic] to the original green chips.

Composition Boards

The feasibility of using dead lodgepole pine and dead white pine for composition board was studied extensively by a joint cooperative research study including: Pacific Northwest Forest and Range Experiment Station, Rocky Mountain Forest and Range Experiment Station, Intermountain Forest and Range Experiment Station and Washington State University (Maloney *et al.*, 1976). In this study it was demonstrated that the wood from dead trees changed very little from that of live trees in characteristics important to the manufacture of composition board. Hammermilled particles, drum-cut flakes, ring-cut flakes, and atmospheric and pressure-refined fibers were evaluated.

Boards were made from each of the five particle types. Each board was then evaluated for internal bond (IB), modulus of rupture (MOR), modulus of elasticity (MOE), linear expansion (LE), and 24-hour water-soak responses.

The only significant difference that occurred between the live and dead classes was in the internal bond responses. It was observed that phenolic bonded, hammermilled particleboards of dead lodgepole had better IB than the boards made from live lodgepole. Pressure-refined fiberboards of live material were better in IB than those of dead material when bonded with urea. The IB for drum-cut flakeboards was quite low for both the live and dead material.

For MOR, hammermilled particleboards of the live lodgepole material range from 1.5 to 2 times better than the particleboards made from dead lodgepole material. The particleboards made from live white pine were only 1.3 to 1.6 times better than the dead white pine material particleboards. These differences were attributed to the live material

having superior particle geometry. Fiberboards were all about the same in MOR with the boards made of phenolic bonded live white pine material being slightly better. Flakeboards of live material range from 1.1 to 1.5 times stronger than those of dead material.

Each species showed similar MOE values when comparable particles were used. Hammermilled particleboards of live material showed up to a 1.4 times greater MOE than those of dead material. Again this was attributed to the superior particle geometry of the live material. Fiberboards were similar in MOE between material classes eccept that the fiberboards made from live white pine were slightly stiffer than the rest of the fiberboards. Flakeboards had the highest MOE values of any of the composition boards. The live class material made boards that ranged up to 1.3 times stiffer than the flakeboards made from the dead material. All board types from both live and dead material responded similarly to the 24-hour water soak test.

All boards absorbed more water than was expected in the linear expansion tests. This appeared to be due to species effect. Again due to its superior particle geometry, the live material had better (lower) LE. For fiberboard, the boards made from dead white pine had higher LE values while the reverse was true for the lodgepole pine boards. All the flakeboards had very good LE values and were better than any of the other type of boards in this property.

The pH and buffering capacity, which are important to resin compatibility, were essentially the same for both the live-tree wood material and the dead-tree wood material.

The characteristics most often associated with dead-tree wood are deep checking, widespread stain, pockets of decay, low moisture content

and loss of bark and have been found to have few harmful effects and in some respects to be actually advantageous in the manufacture of composition board. The presence of deep checks caused additional surfaces to be exposed to weathering and oxidation. This surface area was, however, only a fraction of the new surface area generated in any of the particle-generating processes. The presence of sapstain which was widespread had little effect on the milling properties of resin compatibility. The presence of decay in the form of sap-rot or heart-rot occurred in such small amounts that its effect was negligible when mixed thoroughly with the rest of the furnish, which occurs automatically in the manufacturing process. The absence of bark was considered an advantage since its removal is desirable in current manufacturing processes. The reduced moisture content not only reduces transportation and drying cost but also reduces the power requirement for hammermilling of chips. Moisture content had little effect on the power requirements for the other particle-generation methods. This study also showed that the lower the moisture content at milling the higher the internal bond strength. Though this study did not assess it, the reduced moisture content should reduce the rate of deterioration in stored logs or chips. It was concluded in this study that material from both dead lodgepole pine and dead white pine could be used effectively in the manufacturing of various types of composition board even after many years of standing dead. Suitable properties were found in almost all cases studied. All the lodgepole composition boards had relatively poor linear expansion, failing to meet commercial standards, except in flakeboards.

Fuelwood

In 1978 a comprehensive review was done by Tillman on the use of wood as an energy resource. Tillman presented the aggregate statistics for wood fuels consumption in the United States for 1976 (see Table 1).

Table 1. Wood Fuels Consumption in the United States for 1976.

User group	Wood and wood residue utilization (in 10^{12} Btu)
Pulp and paper	982
Sawmills, plywood mills, and veneer mills	70
Metallurgical industries	12
Other industries	100
Residential	400
Charcoal	15
Total	1579

Table 2 (Tillman, 1978) shows the wood fuels consumption for the forest products industry in 1976.

Table 2. Wood Fuels Consumption for the Forest Products Industry in 1976.

Industry	Energy supplied by wood fuels (in 10^{12} Btu)	Total energy consumed (in 10^{12} Btu)	Wood based energy, % of total fuel consumed
Lumber	35	118	29.7
Plywood	35	70	50.0
Pulp and paper	982	2193	44.8

From this table it can be seen that the pulp and paper industry is the dominant single force in consumption of wood fuels. This is because the spent pulping liquor contains energy-rich lignin and the pulping chemicals. Recovery of the pulping chemicals is essential to efficient operation. The remaining lignin is then available for combustion. The saving of the transportation costs for alternative fuels and the saving of the disposal costs for the unwanted bark, sawdust and hogged fuel shows why there are similar rates of energy self-sufficiency among the rest of the forest products industry.

The use of wood as a fuel when these optimum conditions are not present is limited at best. Grantham (1978) showed that given 1977 prices for coal, dead lodgepole pine timber, and transportation prices, there was little advantage in using dead pine hauled into a central generating plant in Oregon over a 100 mile radius than in using Wyoming coal. This assumed a price of \$20 per ton delivered for the Wyoming coal and a price of \$13.40 per ton of air-dry pine (16.7% moisture content). The transportation cost was approximately \$0.10 per ton mile.

As illustrated in Table 3 the main disadvantage of using wood as a fuel is its Btu per pound value.

Table 3. A comparison of Btu/lb and Btu/ft^3 for selected fuels.

Fuel	Btu/lb	Btu/ft^3
Utah coal	14,170	676,000
Wyoming coal	14,410	676,000
Douglas fir bark	9,500	220,000
Pine bark	8,780	220,000
Wood	9,000	234,000

Dead pine does have an advantage over live pine in its use as a fuel because of its lower moisture content. Energy is required for the heat of vaporization to remove the water in the wood during combustion. Figure 1 shows this relationship between Btu/lb and moisture content.

To overcome these disadvantages, work has been done in combining coal dust with sawdust in a ratio of 5:1 and pressing it into pellets. Fuel of this kind provides a higher flame temperature resulting in a more complete combustion of the sawdust. This type of fuel also results in a less negative effect of the moisture due to more rapid evaporation. This method is in use today in the forest products industry to a limited extent.

Other approaches include conversion of wood into alternative fuel forms. These include pyrolysis, gasification, hydrogenation, enzymatic hydrolysis followed by fermentation, and anaerobic digestion. Pyrolysis, gasification and hydrogenation show promise and are reemerging today. Fermentation and digestion are not particularly well-suited for energy recovery (Tillman, 1978). These techniques will not be discussed further but instead the reader is referred to Tillman for a comprehensive update of these techniques.

Solid Wood Products

The use of dead wood in solid wood products can be further divided into sawn lumber and round wood. Round wood includes uses as power poles, fence posts and log homes. A study conducted to determine the suitability of beetle-killed lodgepole for use as power poles (Tegethoff *et al*., 1977) found that many trees were suitable for poles even after being beetle-killed. The study showed that of the pole quality trees

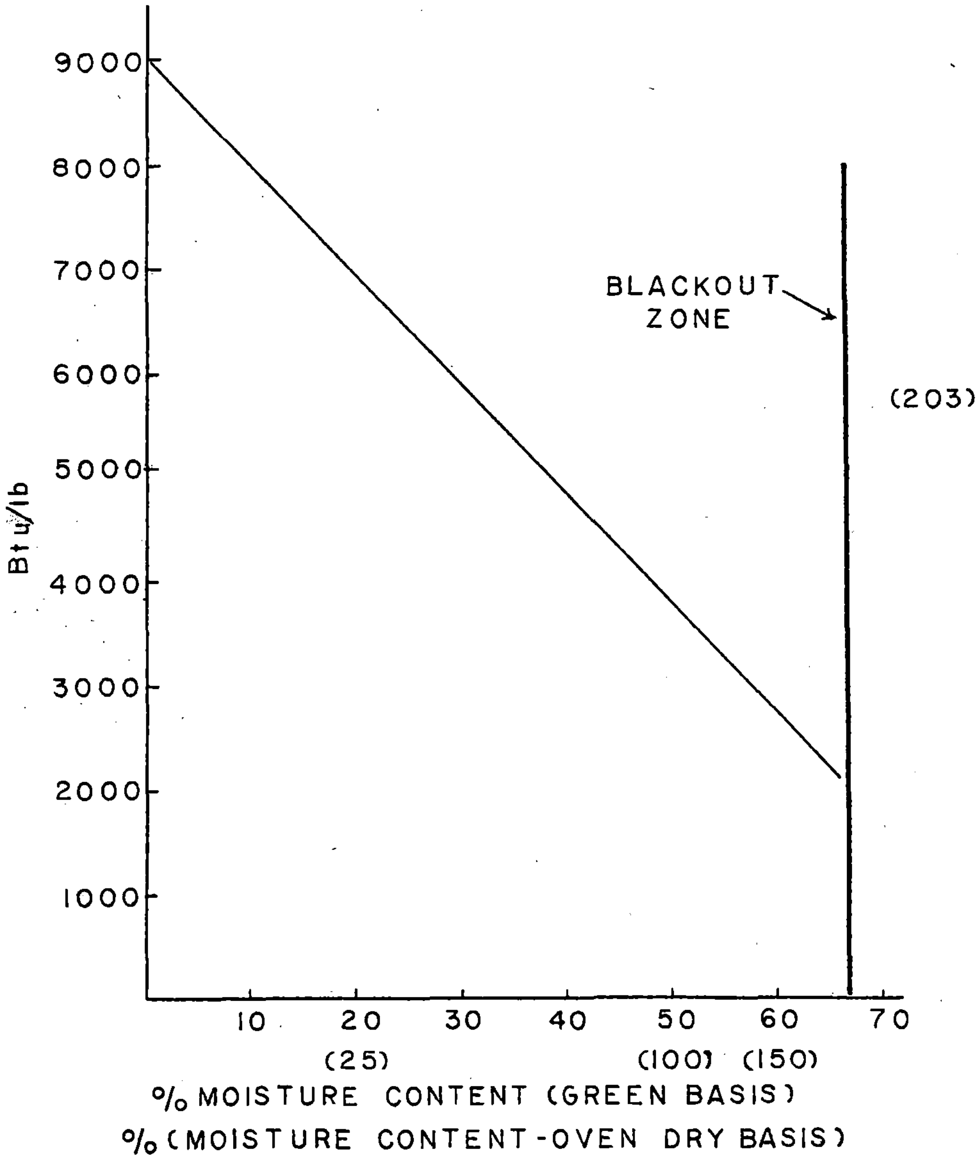

Figure 1. The influence of moisture on the heating value of wood.

that had been dead longer than 5 years, 70 percent were sound enough to use as poles. Ninety-four percent of the pole-quality trees that had been dead less than 5 years were judged to be sound. Long butting was necessary to eliminate basal defects in 76 percent of the trees that had been dead less than 5 years and in 94 percent of the trees that had been dead longer than 5 years.

Because of the presence of blue stain and the increased permeability associated with it, treating schedules would have to be modified. A study of the treatability of dead lodgepole pine (Lowery, 1978) showed that the pressure treating schedules could be reduced from the 3½ hours required for air-dried green posts to 45 minutes for dead lodgepole. All posts met the preservative retention specification of 0.40 pound per cubic foot of water borne type B salts. This same study reduced the time required for the steeping method from 24 hours to 6 hours. Six hours, however, proved to be an insufficient amount of time to meet the preservative retention specification of 0.30 pound per cubic foot of a 5 percent solution of pentachlorophenol in a light crude oil. The actual retentions ranged from 0.00 to 0.28 pound per cubic foot, with the average retention being 0.10 pound per cubic foot. This study, nevertheless, showed that the reduced treating times and the elimination of the air-seasoning time required for green posts makes the use of dead trees as fence posts advantageous.

Another market for round logs is their use in log homes. Peckinpaugh (1978) listed the following specifications as the basic criteria for acceptable house logs regardless of the type of construction.

1. free from rot
2. no spiral checks

3. 1/4 inch minimum check width
4. 7 inches minimum diameter
5. minimum length is 16 feet
6. straight, no crooks, or minimum sweep
7. little taper, less than 3 inches in 40 feet

The majority of house logs are either shaped on a planer, turned on a lathe, or sawn on two sides. From the list of specifications it can be seen that many logs from dead trees could make acceptable house logs. The shaping process could remove many of the surface defects on the dead timber making it more likely to meet the specifications. One problem with using logs from dead timber which also occurs in air-dried lumber is the emergence of round and flatheaded borers from the logs or the air-dried lumber (Levi and Dietrich, 1976). These borers attack standing trees and logs but do not reinfest seasoned lumber. Kiln drying of the wood kills the borers and prevents their emerging from the wood of a finished home. Kiln drying of whole logs, however, is both impractical and uneconomical.

In a study by Lowery (1978) it was concluded that lumber from dead trees could be dried in about half the time requred to dry green lumber. In this study the moisture content and moisture gradient of dead lumber from both dead white pine and dead lodgepole pine was measured. The average moisture content of the dead white pine was 23.7 percent. The average moisture content of the dead lodgepole pine was 23.1 percent. These averages were about half the moisture contents reported for green lumber of the same species. Test sections cut from a sample of the dead lumber indicated that there was essentially no moisture gradient and only a slight amount of drying stresses. This indicates that any

drying schedule should not have too large an initial wet-bulb depression in order to minimize the development of drying stresses. These schedules could also use higher initial drying temperatures. The advantages of kiln drying lumber from dead wood can only be realized if the sawmills separated the dead wood from the green wood prior to drying. The author's personal correspondence with several sawmill operators as well as a survey by Sinclair and Ifju (1977) indicated that a large number of sawmill operators were unwilling or unable to separate the material prior to processing.

The effect of blue-stain fungi, a prominent characteristic of beetle-killed wood on the strength and stiffness of wood is generally insignificant with the exception of toughness (Findlay and Pettifor, 1937, 1939). Toughness was found to be significantly reduced in the blue-stained wood, the amount of reduction being related to the degree of staining (Sinclair _et_ _al_., 1978). The reduction in toughness was as high as 40 percent for Scots pine (Findlay and Pettifor, 1937). A recent study (Sinclair _et_ _al_., 1979) involving the strength loss of beetle-killed southern pine found significant reductions in MOR and MOE in beetle-killed material harvested within 12 months of foliage fade. A mean reduction of 19 percent in MOR and 11 percent in MOE were observed in wood taken from beetle-killed trees two full warm seasons after foliage fade. This discrepancy between investigators could be due to the climatic conditions of the southern United States being so much more favorable to the spread of decay and the fact that Findlay's and Pettifor's material was laboratory innoculated.

The biggest disadvantage of using dead wood is the loss of revenue due to a reduction in the quantity of quality lumber produced from a

given volume of dead timber as compared to green timber. One study conducted on lodgepole pine in British Columbia (Dobie and Wright, 1978) scaled the logs by the rules of both the Firmwood and the Lumber Cubic scales. The Firmwood scale, which is the official scale of British Columbia allows deductions only for rot and lack of wood. The Lumber Cubic scale, which is used in some parts of the United States, allows deductions to also be made for the presence of severe checks, shake, sweep, and crook. In this study the lumber recovery factors mill tally/log volume) based on the Firmwood scale diminished as the tree quality deteriorated (see Table 4). Based on the lumber cubic scale the trees with gray loose bark which had the poorest lumber quality had the highest LRF. This was because the allowable deductions using this scale were sufficient to more than compensate for the lower quality. As seen in Table 5 the longer the trees had been dead, the poorer the lumber grade yield. The 'red top' trees were trees that had been dead 2 or more years but still retained their needles. The 'gray tight bark' trees were trees that had no foliage remaining and had probably been dead for 4 or more years. The presence of loose bark and deep checking was indicative of trees that had been dead longer than the 'gray tight bark' trees.

Table 4. Lumber Recovery Factors (fbm/ft^3) for Lodgepole Pine.

fbm/ft^3 Firmwood Scale	Material	fbm/ft^3 Lumber Cubic Scale
5.71	Green Top	5.82
5.59	Red Top	5.73
5.31	Gray Tight Bark	5.69
5.10	Gray Loose Bark	6.79

Table 5. Lumber Grade Yield and Value from Beetle-killed Pine in British Columbia for Lodgepole Pine.

Quality Group	Lumber Grade (Dimension) #2 & BTR %	#3 %	Econ %	$/m³ of Log* Firmwood Scale	Lumber Cubic Scale
Green Top	84	11	5	47	47
Red Top	82	14	4	46	46
Gray Tight Bark	77	17	6	43	45
Gray Loose Bark	63	30	7	40	48

*January 1977 price

Another recovery study was conducted in Colorado for Engelmann spruce that had been dead 20-25 years (Keepf, 1978). The LRF and lumber grade yield results are shown in Tables 6 and 7, respectively.

Table 6. Lumber Recovery for Engelmann Spruce.

Quality Group	Cubic Recovery LRF	Mill Overrun %
Live Engelmann spruce	8.06	51.2
Standing dead with straight check	7.41	43.8
Standing dead with spiral check and down dead	NA	29.2

Table 7. Lumber Grade Yield for Engelmann Spruce.

Quality Group	Lumber Grade (Dimension) #2 & BTR %	#3 %	Econ %
Live	55.32	18.95	11.08
Standing dead with straight check	43.72	36.95	10.59
Standing dead with spiral check and down dead	27.95	47.80	17.13

Again the quality and quantity of lumber produced was less for the dead timber. From the literature review the utilization of beetle-killed wood requires removal of infested or dead trees.

CHAPTER III

PROCEDURES

The first step of this project was to visit sawmills that were currently using beetle-killed material. After this, two mills were selected to obtain the beetle-killed material and a green wood "control" for testing. Material was also collected from live thinnings (5-inch to 7-inch DBH). This collection procedure was based on the assumption that differences exist between live and dead wood. Laboratory tests were to be conducted on the material selected. It was assumed that any differences found would be applicable to other sources of material. In our case both the live and the dead material were collected from the same location. The sawmill selected for obtaining the lodgepole pine material was Star Studs, Inc., located in Afton, Wyoming. Sampled 2 x 4's of live lodgepole, beetle-killed lodgepole, and lodgepole thinnings were collected at this location. The beetle-killed material was further segregated into two classes; (1) material that had been dead less than 5 years and (2) material that had been dead 5 or more years. The logs were marked on the sawdeck after they had been debarked. The principal criterion for classifying the beetle-killed material was excessive weathering of the bole resulting from the loosened bark in standing timber. This lodgepole pine characteristic indicated that the tree had been standing dead at least 5 years. All

the material was sawn into 8-foot studs and transported back to Fort Collins for drying and further testing.

The sawmill selected for obtaining the Engelmann spruce and subalpine fir material was Kaibab Industries, Inc. located in Eagle, Colorado. The beetle-killed material had been dead for 20-30 years so it was easily recognized by its smooth weathered wood and lack of bark. Again, the material was sawn into 8-foot studs and transported back to Fort Collins for drying and future testing.

The next phase of the study consisted of determining the suitability of the various classes of raw material for conversion into various products. The products that were considered are:

yard lumber	corral poles	particleboard
studs	fence posts	dry-formed fiberboard
joist	fencing	insulation:
mine timbers	paneling (siding)	boards
railroad ties	pallets	batts
houselogs	fuelwood (pellets)	filler
utility poles	laminated beams and joists	bark mulches
construction poles		

The rationale underlying this phase of the study was that every end-use of wood entails a unique group of raw material requirements essential, or at least desirable, for successful processing and product performance. The technique selected for evaluating the suitability of each class of material for a particular end-use was an adaptation of the "species profile" comparison first used by Wangaard (1961) for evaluating the use potential of tropical woods. In the current study live lodgepole was used as a standard for comparison. This "modified product profile" technique consisted of determining the key evaluators and their importance weighting factors for each product. A weighted index value was obtained and compared to a value of 100 for the live

lodgepole pine for each product. The key evaluators and weighting factors for each product were based on the combined judgement of the investigators as to their importance of product conversion and use. The following table shows the technical feasibility evaluators and their weighting factors for each product that was evaluated.

Key Evaluators for Yard Lumber (Boards)

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (small clear specimen)	1
Appearance	3
Shrinkage	1
Freedom from warp	3
Freedom from checks	3
Nailholding	2
Ease of seasoning	1
Uniformity	1

Key Evaluators for Joists and Studs

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (full size specimens)	3
Seasoned stiffness (MOE) (full size specimens)	3
Ease of seasoning	1
Shrinkage	1
Freedom from warp	3
Freedom from checks	3
Nailholding	2
Uniformity	1

Key Evaluators for Mine Timbers

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (full size specimens)	3
Seasoned stiffness (MOE) (full size specimens)	3
Treatability	3
Nailholding	2
Specific gravity	2
Ease of seasoning	2
Uniformity	1

Key Evaluators for Railroad Ties

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (full size specimens)	3
Seasoned stiffness (MOE) (full size specimens)	1
Treatability	3
Nailholding	2
Specific gravity	2
Toughness	2
Ease of seasoning	2
Uniformity	1

Key Evaluators for Houselogs

Properties:	Weighting Factors:
Freedom from warp	3
Freedom from checks	3
Appearance	2
Straightness of grain	2
Shrinkage	2
Weatherability	2
Uniformity	1

Key Evaluators for Utility Poles

Properties:	Weighting Factors:
Freedom from warp	3
Freedom from checks	3
Seasoned bending strength (MOR) (full size specimens)	3
Seasoned stiffness (MOE) (full size specimens)	2
Treatability	3
Weatherability	2
Ease of seasoning	2
Appearance	2
Uniformity	1

Key Evaluators for Construction Poles

Properties:	Weighting Factors:
Freedom from warp	3
Freedom from checks	3
Treatability	3
Weatherability	1
Seasoned bending strength (MOR) (full size specimens)	3
Seasoned stiffness (MOE) (full size specimens)	3
Ease of seasoning	3
Uniformity	1

Key Evaluators for Corral Poles (round fence poles)

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (full size specimens)	3
Freedom from warp	3
Freedom from checks	3
Appearance	2
Weatherability	3
Nailholding	2
Uniformity	1

Key Evaluators for Fence Posts

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (full size specimens)	3
Freedom from warp	3
Freedom from checks	3
Nailholding	2
Treatability	3
Weatherability	3
Uniformity	1

Key Evaluators for Fencing

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (full size specimens)	2
Freedom from warp	3
Freedom from checks	3
Shrinkage	2
Weatherability	3
Appearance	2
Univormity	1

Key Evaluators for Paneling (siding)

Properties:	Weighting Factors:
Appearance	3
Shrinkage	2
Freedom from warp	3
Freedom from checks	3
Uniformity	1
(Weatherability)	3

Key Evaluators for Pallets

Properties:	Weighting Factors:
Specific gravity	3
Seasoned bending strength (MOR) (full size specimens)	3
Seasoned stiffness (MOE) (full size specimens)	2
Freedom from warp	2
Freedom from checks	2
Nailholding	3
Toughness	2
Uniformity	1

Key Evaluators for Fuelwood

Properties:	Weighting Factors:
Specific gravity	2
Ease of seasoning	3
Uniformity	1

Key Evaluators for Laminated Beams and Joists

Properties:	Weighting Factors:
Seasoned bending strength (MOR) (small clear specimens)	3
Seasoned stiffness (MOE) (small clear specimens)	3
Gluability	3
Freedom from warp	2
Freedom from checks	2
Uniformity	1

Following is a list of the sources of the key evaluators:

Ease of seasoning: The time in hours it takes 2 x 4 material to reach a 12% moisture content. (Using a standard kiln schedule)

Freedom from warp: The total warp in 16th of an inch was determined for each specimen and then an average value was determined for each class of material. The reciprocal of this value times 1000 gave the freedom from warp value.

MOE and MOR: (from small clear specimens) static bending test procedure was from ASTM D 143 (245-252). The load was applied to the radial surface.

Toughness: The test procedure was based on ASTM D 143 (71-76). An Amsler-type apparatus was used. All specimens were impacted on the radial surface.

Nailholding: The specimen size was 1½"x2½"x6". Two 7-d cement coated sinker nails with coating removed were withdrawn from a face surface and two nails were withdrawn from an edge surface. The actual test procedure was done according to ASTM D 143 (108-113). The average load required to withdraw the nails was used as the evaluator for nailholding.

MOE and MOR: (from full size specimens) The static bending test procedure was from ASTM D 198.

Specific gravity and volumetric shrinkage: This test was determined from small sample blocks that were soaked to above the fiber saturation point and then oven dried. The green volume, oven-dried volume, and oven dried weight were recorded. The shrinkage value was equal to the reciprocal of the volumetric shrinkage times 1000.

Weatherability:	This test procedure was based on ASTM G (23-69) (4,7). In this test, three specimens from each category of material were selected. For each category, a specimen with a knot and a specimen with a check were included. The specimens were placed in an Atlas DHC-R Weather-Ometer for one month. Before and after photographs were taken of the specimens and a gray scale using low angle lighting. From these photographs the investigators ranked the categories.
Gluability:	This test procedure consisted of gluing samples together with a urea formaldehyde adhesive and then cutting out shear block specimens. The shear value was used for the gluability evaluator.
Freedom from checks:	The reciprocal of the total area of the checks opening in square inches was used as the value for the freedom from checks evaluator.
Treatability:	This test procedure consisted of first determining the percent sapwood of each specimen and then placing the specimens in a cold oil soak. The amount of oil absorbed in 36 hours, after statistically correcting for the percent sapwood was used as the evaluator for treatability.
Appearance:	In this test the lumber was first visually graded by a WWPA certified grader. The sum of the dollar value of each grade of lumber times the number of pieces of that grade in each material class was used as the evaluator for appearance.
Straightness of grain:	In this test the grain angle of each piece of material was determined with a stylus. The evaluator for straightness of grain was the horizontal distance required to obtain a one inch rise in the grain angle expressed as a percentage with a horizontal distance of 29 inches being considered perfectly straight.
Uniformity:	This evaluator was determined by summing the coefficient of variation for all the tests. The reciprocal of this value times 100 was used as the evaluator for uniformity.

Methods

The total sample of test material consisted of approximately 140 2 x 4's of: live lodgepole pine, beetle-killed lodgepole that had been dead less than five years, beetle-killed lodgepole that had been dead five years or longer, lodgepole pine thinnings, live Engelmann spruce, beetle-killed spruce that had been dead for 20-25 years, and Engelmann spruce and sub-alpine fir thinnings. After being transported to Fort Collins the lumber was kiln dried. For the lodgepole pine a standard T5-C5 kiln schedule was used (Dry Kiln Operators Manual, 1961). For the Engelmann spruce a T5-B5 schedule was used. The first charge consisted of the beetle-killed lodgepole. The second charge consisted of the live lodgepole and the lodgepole thinnings. The third charge consisted of the spruce-fir thinnings. The fourth charge consisted of the live spruce. The beetle-killed spruce was not dried since its average mositure content was 11.2 percent. The desired final average moisture content was 12 percent. Three full size studs were used as kiln samples for each category of material. From each of these, three 1.5 inch plugs were removed to determine the average moisture content of each category. The kiln samples were removed and weighed every 6 hours. The weight loss of the total charge was also monitored. After drying, 50 percent of the pieces were measured for bow, crook, and twist. This consisted of placing the piece of lumber on a flat table with a clamp at one end (see Figure 2). The bow, crook, and twist was measured in 16ths of an inch by placing a graduated wedge between the table and the specimen. At the same time the specimen was also measured for checks. This consisted of measuring the width and length of the checks in inches. After this a sample of 30 studs were randomly picked

Figure 2. Setup for measuring warp.

from each of the material classes. This material was then graded as light framing material by a WWPA certified grader. The grain angle of this material was then determined by the stylus method (Anderson et al., 1955). Both a face and an edge were measured. The distance required to obtain a 1 inch rise was recorded. A distance of 29 inches or larger was considered to be an arbitrary standard for a straight piece.

This material was then tested non-destructively to determine the dynamic modules of elasticity for each piece. The test procedure used was for transverse free vibrations (Pellerin, 1965). This consisted of supporting each piece of material flatwise (see Figure 3) at its ends. The piece was then caused to vibrate slightly. This vibration was monitored and

recorded by a photoelectric cell and an oscillograph (see Figure 3). The dynamic modulus of elasticity was determined by the following equation:

$$E_d = \frac{f_n^2 \, w \, L^3}{C^2 \, I \, g}$$

Where:

E_d = dynamic MOE (psi)

C = constant dependent upon mode of support, 2.46 for simply supported at the ends

f_n = natural frequency (cycles per second)

w = weight of beam (lbs.)

L = length of span (in.)

I = moment of inertia (in.^{4})

g = acceleration due to gravity (386 in/sec^2)

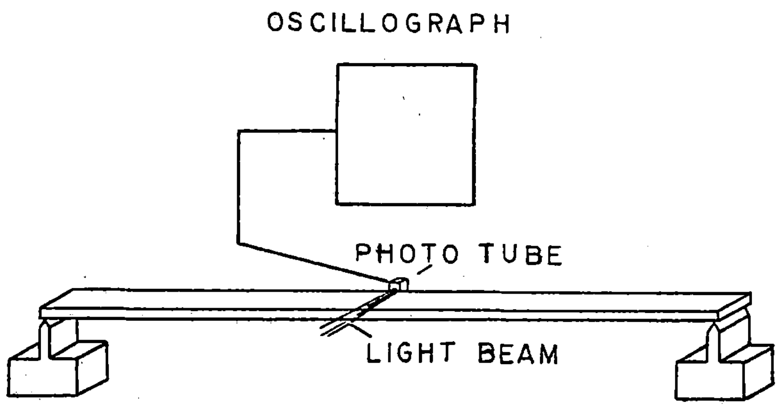

Figure 3. Setup for transverse free vibrations.

After the nondestructive test, each piece was tested to failure according to the ASTM D 198 procedure. The specimen was stressed in third-point loading with a span of 73.5 inches and a cross head speed of .2 inch per minute (see Figure 4). The modulus of rupture and modulus of elasticity were determined by the following equations:

$$MOR = \frac{Pu\ L}{6\ S}$$

$$MOE = \frac{P_{p\ell}\ L^3}{56.35\ I\ \Delta_{p\ell}}$$

Where:

$P_{p\ell}$ = load at proportional limit (lbs)

Pu = ultimate load (lbs)

L = length of span (73.5 inches)

$\Delta_{p\ell}$ = mid-span deflection at proportional limit

S = section modulus (in^3)

I = moment of inertia (in^4)

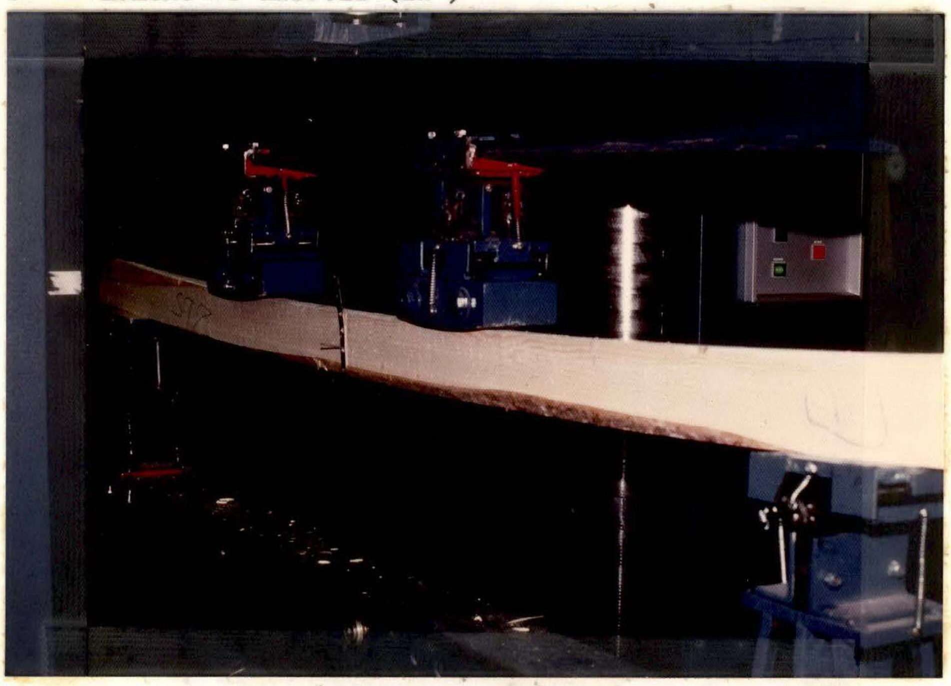

Figure 4. Third point static bending.

In this test a constant I of 3.36 in^4 and a constant S of 3.06 in^3 was used. In this way the material was tested as a 2 x 4 product so that the thinning material was penalized if wane was present.

After the destructive test, one-inch cross sections were cut out of each of the broken pieces. The specimens were first weighed to the nearest 0.1 gram. Next the specimens were soaked until their moisture content was well above the fiber saturation point. Their green volume was determined by immersion. This consisted of taring a beaker of water on the scales. Each specimen was supported in the beaker so that it was completely submerged but was not touching the sides of the beaker (see Figure 5).

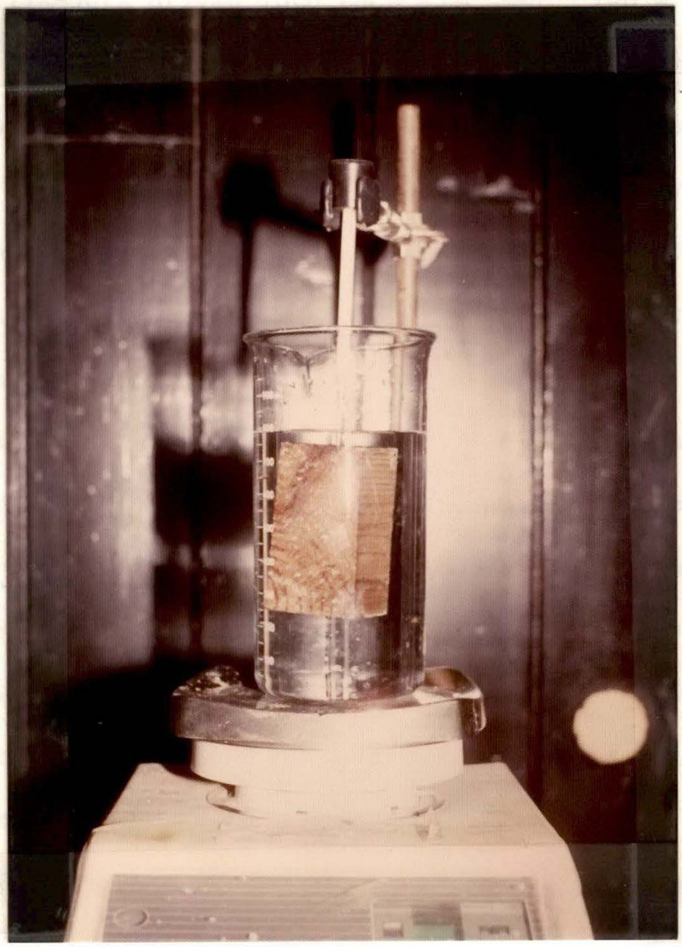

Figure 5. Setup for determining volume by immersion.

The weight on the scales in grams was equivalent to the volume of the specimen in cubic centimeters (weight of water displaced). The specimens were then oven-dried, weighed and dipped into melted paraffin. The excess paraffin was scraped off and then the oven-dry volume was determined by the method used for the determination of the green volume. From this set of measurements the moisture content at the time of testing, the volumetric shrinkage, and the specific gravity (green volume basis) were determined. Twenty more studs were then randomly picked from each category. From each stud, two six-inch cross sections were randomly cut out. One was trimmed to a 1.5" x 2.5" x 6" test specimen for the nail withdrawal test (ASTM D 143:108-113). Four 7d cement coated nails were driven into each specimen. Two were driven into a face and two into an edge. The location of where the nails were to be driven was predetermined by a template. Each nail was cleaned with steel wool prior to being driven. The nails were driven to a depth of 1 1/4" and were immediately withdrawn on the Universal testing machine with a crosshead speed of .075 inch/min. (see Figure 6). Each nail was used only once.

The other six-inch specimens were used for the treatability test. The percent sapwood of each of these specimens was first determined, then each block was end-coated with two coats of latex paint. The blocks were then weighed and placed in a 4 percent solution of "Penta-40" and number 2 diesel fuel. The blocks were removed from this cold soak every 12 hours and weighed. The blocks were treated for a total of 36 hours. The amount of preservative absorbed was recorded.

From each of these same studs two small clear specimens were also cut out. One was used for the toughness test and the other was used for

additional static bending tests. For the static bending test the ASTM D 143:245-252 procedure was used except that the radial surface was loaded (see Figure 7). This was done to reduce the effects of the

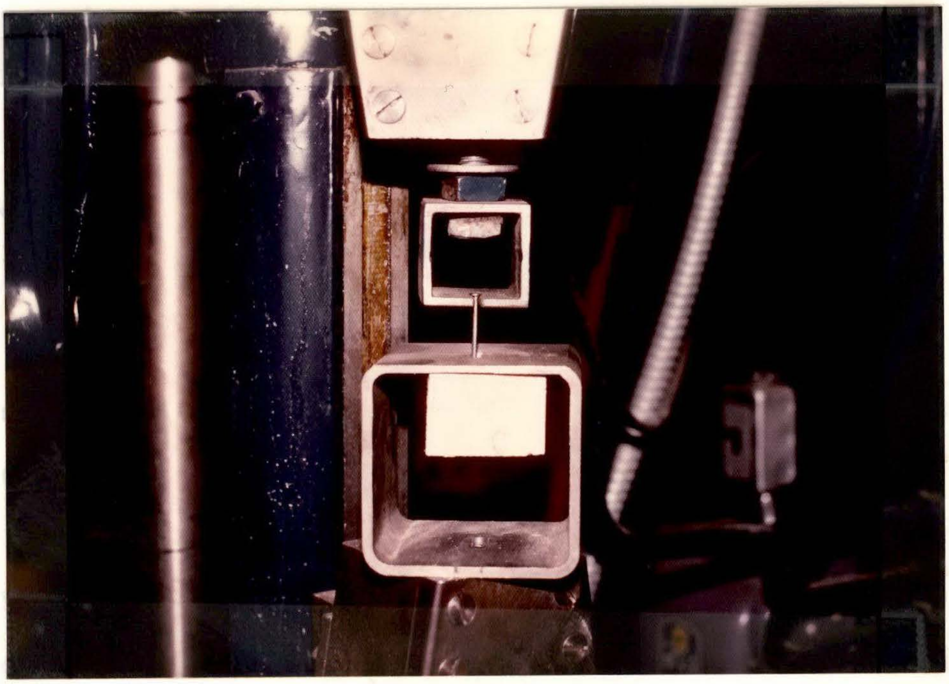

Figure 6. Test setup for nail withdrawal.

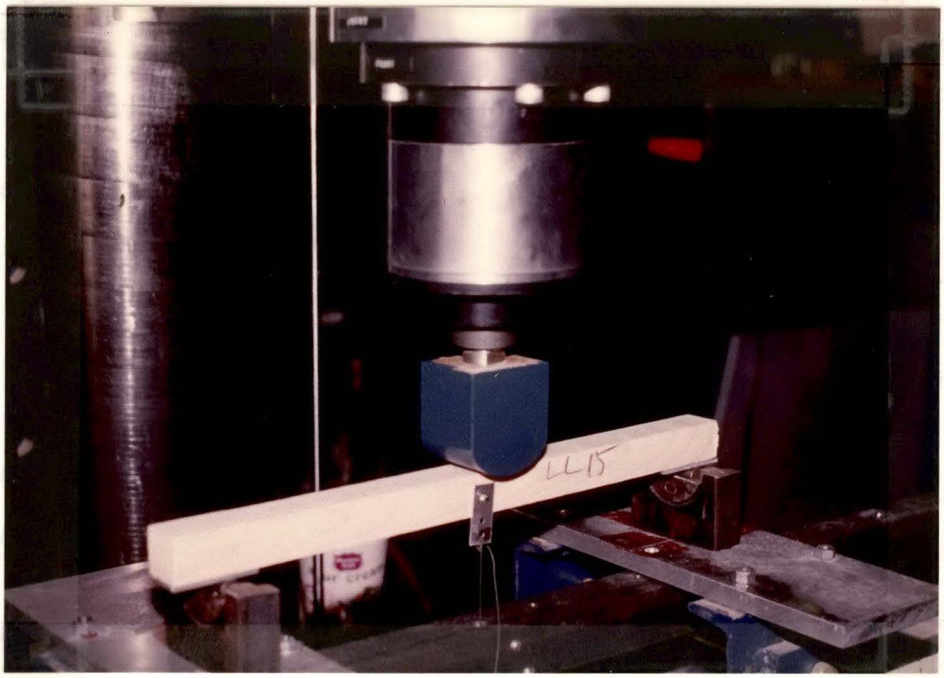

Figure 7. Setup for small clear static bending test.

growth rings. The test specimen was 1" x 1" x 16" in size. Center load and a span length of 14 inches was used. The rate of loading was .05 inch/minute. The modulus of rupture and modulus of elasticity was determined by the following equations:

$$MOR = \frac{3P_u L}{2bh^2} \qquad MOE = \frac{P_{p\ell} L^3}{4\ b\ h^3\ \Delta_{p\ell}}$$

Where:

b = width of specimen (in.)

h = height of specimen (in.)

After testing, the moisture content of each specimen was determined. For the toughness test the ASTM D 143:71-76 procedure was used. The size of the test specimen was 0.79" x 0.79" x 11". The Amsler-type toughness apparatus was used (see Figure 8). The specimens were impacted only on the radial surface. The initial and final angle of the pendulum was read to the nearest 0.1 degree. The toughness was calculated as follows:

$$T = WL\ (\cos A_2 - \cos A_1)$$

Where:

T = toughness (lb. - in.)

W = weight of pendulum (lb.)

L = distance from center of the supporting axis to center of gravity of the pendulum (inches).

A_1 = initial angle (degrees)

A_2 = final angle (degrees)

After testing the moisture content and specific gravity (green volume basis) of each specimen was determined.

Figure 8. Amsler-type toughness apparatus.

From the same sample of studs a 14-inch section was removed from each stud for the gluability test. Each specimen was machined down to a size of 3/4" x 3.5" x 14". Each specimen was then cut into two 3/4" x 3.5" x 6" specimens and glued together with a urea-formaldehyde adhesive. A spread rate of 40 pounds per 1000 square feet of surface area was used with a clamp pressure of 150 pounds per square inch. For each material class the twenty specimens were divided into two groups. One group had a closed assembly time of less than 5 minutes which was

optimum. The other group had a closed assembly time of 15 minutes which was the maximum allowable closed assembly time. This was done because the beetle-killed material was suspected to be more permeable so that the assembly time might be more critical to prevent a starved joint. Also, since this test procedure would require several batches of adhesive to be mixed up, the specimens were randomly assigned to each batch to reduce the variance caused by the different batches. A viscosity test was also conducted on each batch of adhesive to check the uniformity of the batches. This viscosity test consisted of dipping a tared glass rod into each batch of adhesive and then allowing the adhesive to drip for 30 seconds. The amount of adhesive remaining on the rod was weighed. If the weight of the adhesive remaining on the rod varied more than .05 gram the batch was discarded and a new batch was made. After the glue was cured, one shear block specimen was cut out from each of the glued assemblies. The shape of the final glue shear blocks is shown in Figure 9. The blocks were then sheared on the Universal testing machine with a cross-head speed of .015 inch/minute (see Figure 10).

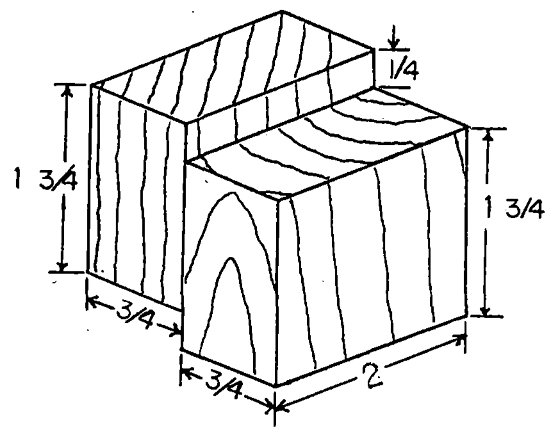

Figure 9. Diagram of shear block.

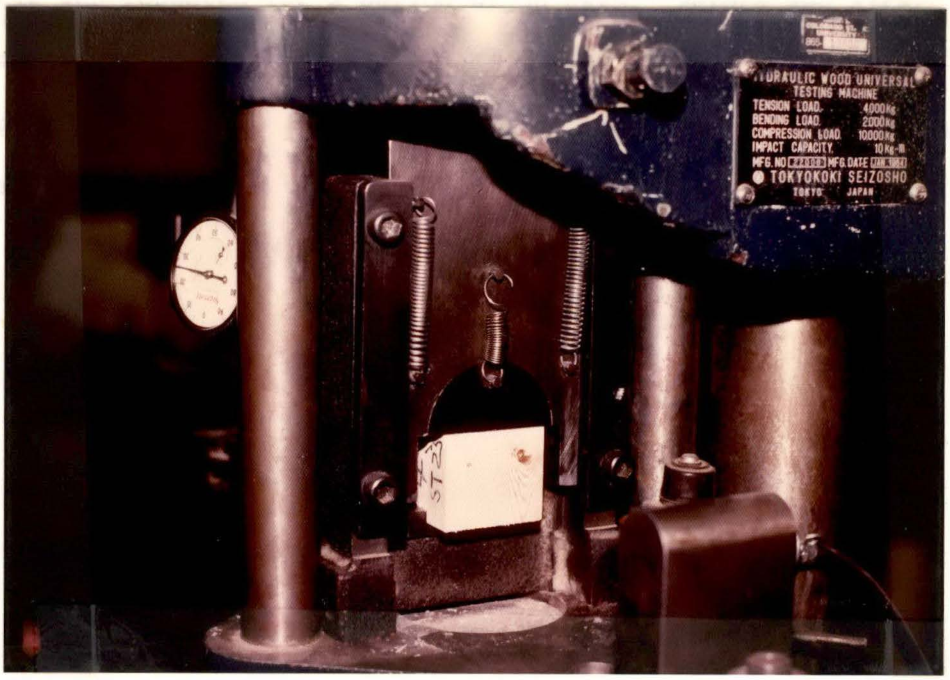

Figure 10. Setup for shear block tests.

For the weatherability test, 3 specimens from each category were cut to 1/2" x 2 3/4" x 10" in size. Of the three specimens, a clear specimen, a specimen with a knot, and a specimen with a check present was used. An Atlas model DMC-R Weather-Ometer (see Figure 11) with the ASTM G 23-69 (4.7) recommended cycle (cam Nol 47) was used. The cycle was 102 minutes of "light" only followed by 18 minutes of "light with spray" repeating for a total of 18 hours. A period of six hours "without light or spray" followed the 18 hour period. During the 18 hour period of "light and spray," the temperature, except when the specimen spray was on, was 63 ± 5°C. The relative humidity of the air during the 6 hour period of darkness without spray, the temperature was 24 ± 2°C and the relative humidity was 95 ± percent. This 24-hour

cycle was repeated for a period of 30 days. Before and after testing photographs were taken of the specimens and a gray scale using low angle lighting. From these photographs the weatherability of each of the specimens and categories was ranked by the investigators.

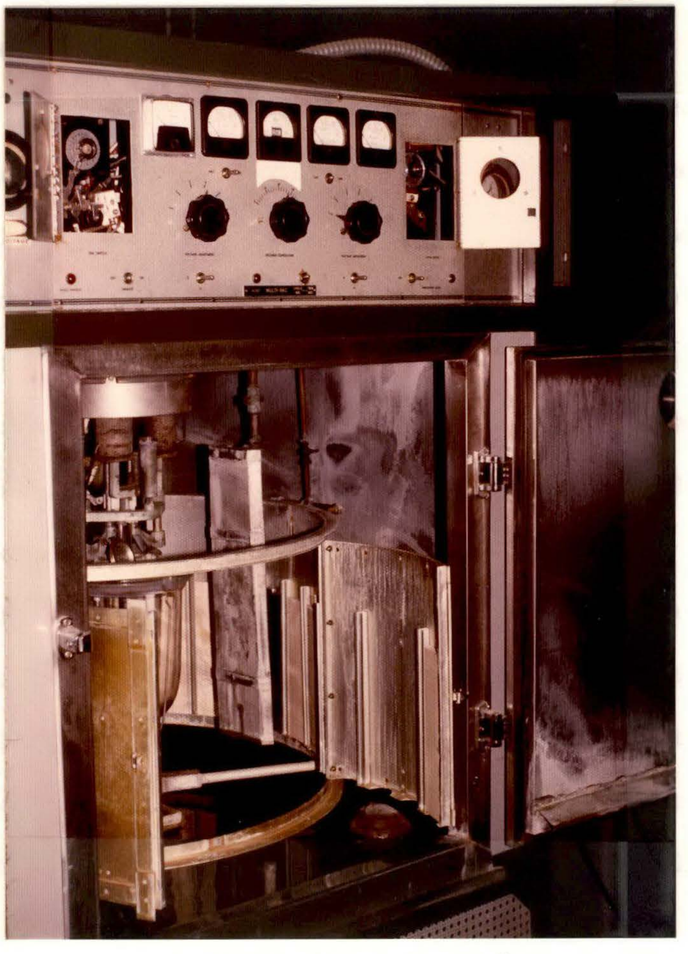

Figure 11. Weather-Ometer.

Other tests, in addition to the tests used for the product profile, were conducted to help explain any physiological or chemical changes that may occur in beetle-killed wood. These tests were one percent caustic soda solubility of wood and hot water solubility of wood.

1% NaOH Solubility

The material used for the toughness test was reduced to wood flour for the "One Percent Caustic Soda Solubility of Wood" (ASTM D 1109). The wood flour was ground to pass a 40 mesh screen but be retained on a 60 mesh screen. The wood flour of each specimen was combined according to the seven material classes. The weight of each of the test samples was equivalent to 2 ± 0.1 grams of moisture-free wood. The test sample was placed in a 200 ml tall-form beaker and 100 ml of a one percent solution of NaOH was added. After stirring, the mixture was placed in a boiling water bath. The beaker was left in the bath for one hour and stirred three times at intervals of 10, 20, and 30 minutes after the beaker was placed in the bath. At the end of one hour, the contents were filtered by suction in a tared crucible. The wood flour was then washed, first with 100 ml of hot water then with 50 ml of a 10 percent solution of acetic acid and then thoroughly with hot water. The contents of the crucible were then dried to a constant weight at 100 ± 3°C, cooled in a desiccator and weighed. The results were reported as a weight percentage of matter soluble in a one percent caustic soda solution on a moisture-free basis and calcualted as follows:

$$\% \text{ solubility} = (W_1 - W_2)/W_1 \times 100$$

Where:

W_1 = the weight of moisture free wood prior to the test

W_2 = the weight of oven-dried specimen after treatment with the NaOH

The unused wood flour from the one percent caustic soda solubility test was used for the "Hot Water Solubility of Wood" (ASTM D1110). For each class of material a test sample was weighed. The weight of each of the test samples was equivalent to 2 ± 0.1 grams of moisture-free wood. The test sample was placed in a 500 ml Erlenmeyer flask and 100 ml of distilled water was added.

The flask was then connected to a reflux condenser and placed in a boiling water bath. The beaker was left in the bath for three hours. At the end of that time, the contents were filtered by suction in a tared crucible. The wood flour was then washed thoroughly with hot water. The contents of the crucible were then dried to constant weight at 105 ± 3°C, cooled in a desiccator and weighed. The results were reported as a weight percentage of matter soluble in hot water on a moisture-free basis and calculated as follows:

$$\% \text{ solubility} = (W_1 - W_2)/W_1 \times 100$$

Where:

W_1 = the weight of moisture-free wood prior to the test

W_2 = the weight of the oven-dried specimen after treatment with hot water

CHAPTER IV

RESULTS AND DISCUSSION

Property Evaluation

The kiln drying phase of this study was conducted by means of five kiln charges. The results are given in Table 8. From this summary, it can be seen that the dead lodgepole pine had a relative moisture content that was 26 to 53 percent lower than the moisture content of the live lodgepole pine. This caused the dead lodgepole pine to be dried 36 to 48 percent faster than the live lodgepole. This should constitute a saving of time and money to industry. The dead spruce wood averaged 69 percent lower in moisture content than the live spruce and did not require drying since it was already below 12 percent moisture content. This would be an added advantage because it would reduce the number of times that the lumber had to be handled.

Table 8. Average Initial Moisture Content of Material Classes and Drying Time Required to Reach a 12% Moisture Content.

Material Class	Initial Moisture Content (%)	Kiln Charge No.	Drying Time (hrs.) Required to Reach 12% M.C.
Live lodgepole	45.6	2	81
Dead lodgepole <5 years	33.6	1	52
Dead lodgepole 5+ years	21.6	1	42
Lodgepole thinnings	38.0	2	75
Live spruce	36.6	5	41
Dead spruce	11.2	4	0
Spruce-fir thinnings	71.1	3	72

After the drying process, the lumber was measured for checks and warp. From Table 9, it can be seen that the dead material had somewhat more checks than the live material. Furthermore, the longer the material had been dead the more checks were present and the more variation existed. The greater occurrence of checks in the dead material was attributed to the harsh drying conditions that occur when timber was dried on the stump. The thinning material had the fewest checks of any of the material classes. This was attributed to the fewer defects present in the thinning material at the start of processing. The occurrence of the many checks in the live spruce was due to the presence of ring shake which continued to propagate when dried. The presence of these shakes was undoubtedly due to the fact that the live spruce material came from an over-mature stand. These differences in freedom from checks were verified statistically by an analysis of variance (see Summary Table 22).

It must be noted that an analysis of variance showed whether the separation of the material into classes had any affect on the variation of the response of the material to a treatment or test. It does not tell us which of the material classes were statistically different from the rest of the classes. As noted in the analysis for the results of the freedom from warp, a statistical difference in a property does not mean that a practical difference exists between the material classes.

From Table 9 the results for the freedom from warp test showed no logical pattern; however, the analysis of variance showed that there was a significant difference (see Summary Table 22). From the practical viewpoint there was no difference in the amount of warp present in these classes. The warp was measured in 16ths-of-an-inch and the range for

Table 9. Freedom from Checks and Freedom from Warp for Each Material Class.

Material class	Sample size	Freedom from checks[1]		Freedom from warp[2]	
		Mean	C.V.%	Mean	C.V.%
Live lodgepole	37	73.2	61	9.4	40
Dead lodgepole <5 years	69	56.8	87	8.2	34
Dead lodgepole 5+ years	60	37.1	130	9.0	34
Lodgepole thinnings	70	88.9	35	8.6	34
Live spruce	69	38.1	127	8.4	31
Dead spruce	65	34.1	139	10.4	26
Spruce fir thinnings	59	73.5	60	7.9	38

[1] Freedom from checks - Reciprocal of the total area of the openings in square inches x 100 (100 = a piece with a in^2 check).

[2] Freedom from warp - Reciprocal of total deflection from plane measured in 16ths of an inch x 100 (100 = a piece with a 1/16 inch total deflection).

all material classes was 9.7 to 12.6 16ths-of-an-inch. It should be noted that the thinning material had a relatively small amount of overall warp but some pieces were warped so badly that they could not be used for the full size bending tests due to the large amount of warp present in one plane. This was primarily due to the presence of the pith and the presence of juvenile wood, on or near the surface of most of the lumber in the thinning classes of material.

For the appearance evaluation of lumber, dollar values were assigned to each lumber grade. The dollar value for the standard and better and the utility grades were obtained from a February 16, 1979 Random Lengths Weekly Lumber Price Guide. No price for economy lumber was available in the guide, so this price was obtained from a local sawmill's price list. The value for the cull material was estimated from the prices that local sawmills sold their cull material for firewood. This low value for the cull material did not take into account the potential value for pulp chips since there was no existing pulpmill in the region. For the appearance test, the number of studs in each grade was multiplied by the dollar value of that grade and the average determined for each material class gave the appearance value for the class. Table 10 lists the summary for this test.

From these results it can be seen that live lodgepole pine was more valuable appearance-wise than the dead lodgepole pine. The live spruce was downgraded because of the higher amount of checks present. Both the lodgepole pine and the spruce-fir thinnings were downgraded due to the large amount of wane present. An analysis of variance showed a significant difference in each case (see Summary Table 22).

Table 10. Dollar Value of Material Classes When Graded as Light Framing Material.

Grade	Price/MBF
Std and better	$233
Utility	$171
Economy	$145
Cull	$ 10

		Appearance[1]	
Material Class	Sample Size	Mean ($)	C.V. (%)
Live lodgepole	15	196.5	19
Dead lodgepole (<5 years)	28	180.5	26
Dead lodgepole (5+ years)	24	181.8	15
Lodgepole thinnings	27	140.0	55
Live spruce	27	171.9	38
Dead spruce	30	169.0	25
Spruce-fir thinning	21	144.7	51

[1] Appearance value = the number of studs in each grade times the dollar value of that grade summed up and averaged for each material class.

The material was then measured for grain angle. In this test, a face and an edge were measured for the slope of grain. The total grain angle determined was equivalent to the resultant of the two slope vectors. The straightness of grain value was equal to the horizontal distance required to obtain a one-inch rise which was multiplied by 3.44838. This gave a horizontal distance of 29, which was considered a standard for a straight piece, a value of 100. In this test, the subalpine fir thinnings were separated from the spruce thinnings even though there were only three subalpine fir pieces. Table 11 depicts the results of this test.

Table 11. Straightness of Grain for Each Material Class.

Material Class	Sample Size	Horizontal[1] Distance (inch)	Straightness of Grain[2] Mean	C.V.%
Live lodgepole	14	25.5	87.9	21
Dead lodgepole (<5 yrs)	29	22.3	76.9	37
Dead lodgepole (5+ yrs)	30	21.3	73.3	37
Lodgepole thinnings	31	26.4	90.9	18
Live spruce	30	26.0	89.8	21
Dead spruce	30	23.8	82.1	29
Spruce thinnings	27	23.9	82.4	29
Fir thinnings	3	22.3	77.0	52

[1]The horizontal distance required to obtain a 1 inch rise in the slope of the grain.

[2]Straightness of grain = 3.448 x horizontal distance (1/29=100 an arbitrary standard for a straight piece).

The analysis of variance revealed a significant difference between the material classes (see Summary Table 22). From a practical standpoint, however, there was little difference in the grain angle of the different classes of material as far as strength was concerned. A slope of grain smaller than 1 in 20 is considered to have no effect on strength values. As seen from the horizontal distances in Table 11, all the material classes had an average slope of grain smaller than 1 in 20.

From the full size specimen vibrational and destructive tests, the dynamic modulus of elasticity, static modulus of elasticity, and modulus of rupture were determined. The fact that the distribution of the test results were skewed to the right indicated that the results had to be transformed logarithmically to normalize the distribution. The analysis of variance was conducted and the antilog of each material class was calculated to determine the strength values. Table 12 shows these results of the full size specimen strength tests. Each of the three strength properties were thusly compared. The analysis for the dynamic modulus of elasticity showed that there were no significant differences between the seven material classes (see Summary Table 22). The analysis for the static modulus of elasticity showed similar results. As shown in Table 12, however, the live and dead spruce were considerably lower in both their strength and stiffness values as compared with the other material classes. The inclusion of the outliers (the studs with a strength and stiffness values equal to zero) created a bias in the statistical analysis. Summary Table 22 shows the extent of the significant differences between the material classes for the strength properties when the outliers were removed. The outliers were included in the analysis since it is extremely difficult to justify

Table 12. Summary Table for Full-size Specimen Bending Tests by Material Class.

Material Class	Sample Size	Moisture Content		Dynamic E[1] (X10^6psi)		MOE[1] (X10^6psi)		MOR[1] (psi)	
		Mean	C.V.%	Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Live lodgepole	15	7.37	12	1.383	2	1.277	2	4478	7
Dead lodgepole (<5 years	28	8.47	95[2]	1.329	2	1.133	2	3540	6
Dead lodgepole (5+ years)	24	6.90	7	1.303	1	1.179	2	2975	8
Lodgepole thinnings	27	7.11	6	1.656	1	1.484	2	7310	4
Live spruce[4]	27	6.61	56[2]	.680	20[3]	0.628	20[3]	2222	21[3]
Dead spruce (20-25 years)	30	6.11	10	.615	19[3]	0.585	19[3]	2351	19[3]
Spruce-fir thinnings	21	7.80	38[2]	1.239	1	1.252	2	6192	4

[1]Mean values and analysis of variance were obtained from a log normal distribution.

[2]The high coefficient of variation was due to one stud in each of these material classes which contaminated the distribution due to an extremely high % M.C.

[3]The high coefficient of variation was due to one stud in each of these material classes which broke due to handling prior to testing thereby giving it strength and stiffness values of zero.

[4]The strength values for live spruce do not correspond to the published strength values of Engelmann spruce in Colorado and Wyoming (Bodig 1969) (MOE at 12% M.C. = 1.29 x10^6 psi and MOR at 12% M.C. = 6408 psi.) This tends to indicate that the live spruce material class was not a representative sample of the Engelmann spruce in Colorado and Wyoming.

discarding a test value that did not occur by an experimental error. The test did show that the modulus of elasticity, both dynamically and statically changed very little between the live and dead material of the same species. The analysis for the modulus of rupture, however, showed a significant difference as also shown in Summary Table 22. The pine material, dead for less than 5 years, showed a decrease of 21 percent for the average modulus of rupture. The spruce material showed no difference in the live and dead material.

The reason the MOR of dead lodgepole pine was lower than the MOR of live material; whereas, the MOE seemed unaffected is due to the fact that the whole piece of lumber determines the stiffness and the weakest point determines its MOR. In the live spruce material the low strength values were caused by the fact that the live spruce material was not a representative sample. The strength values for the live spruce did not correspond to the published strength values of Engelmann spruce in Colorado and Wyoming as determined by Bodig (1969). He found that full size lumber tested at 12 percent moisture content had an average MOE of 1.29×10^6 psi and an average MOR of 6408 psi. The thinning material strength properties were higher and this was attributed to smaller knots and a somewhat higher specific gravity.

Linear regressions were computed between the dynamic E (Ed) and MOE, the dynamic E and MOR, and MOR and MOE to assess whether nondestructive machine grading of the dead material would be feasible. Summaries of these correlations by material classes are listed in Table 13. These correlation coefficients were extremely low for the pine thinnings and was largely due to the presence of wane and warp in a single plane in

Table 13. Correlation Coefficient(s) for Full-size Specimen Strength Test Parameters by Material Class.

	All Data	All Pine	Live Pine	Dead Pine (<5 yrs)	Dead Pine (5+ yrs)
Ed vs MOE	.780	.684	.940	.921	.829
Ed vs MOR	.669	.688	.839	.486	.575
MOE vs MOR	.669	.627	.866	.715	.494

	Pine thinnings	All spruce	Live spruce	Dead spruce	Spruce for thinnings
Ed vs MOE	.151	.861	.954	.763	.760
Ed vs MOR	.525	.637	.617	.587	.553
MOE vs MOR	.210	.700	.655	.648	.473

some specimens. This caused several of the specimens not to fit properly in the test apparatus and created an error brought about by introducing a shear component. The spruce-fir thinnings did not have correlation coefficients as low as the pine thinnings; however, some of the spruce specimens had such a high degree of wane and warp present that they would not fit into the testing apparatus. The dead pine material had lower correlations with MOR than the dead spruce material because the dead pine logs (average dbh 12 inches) were much smaller than the dead spruce (average dbh 18 inches). The larger diameter logs allowed the sawyer to saw more for grade in the spruce than in the pine material. This greatly increased the number of "spike knots" in the dead pine material which likewise altered the strength and stiffness relationships. In practice, however, when using nondestructive machine grading a visual grader is used to downgrade material for the presence of such defects as spike knots to which the grading machine is insensitive. The reason the correlation coefficient was low for the regression between Ed and MOE for the pine, dead 5 or more years, was attributed to the presence of two studs that had lost much of their flatwise stiffness due to spike knots but still maintained stiffness in the edgewise direction.

The reason for not discarding these outliers from the analysis lies in the fact that this study was a product evaluation study and sample pieces had to be tested whenever possible. This eliminated high grading of the population.

One-inch cross-sections were removed from each of the pieces tested. These cross-sections were used to determine the moisture

content at the time of testing, the volumetric shrinkage, and the specific gravity. These results of the specific gravity and the volumetric shrinkage tests are listed in Table 14. The specific gravity

Table 14. Mean Specific Gravity and Mean Volumetric Shrinkage by Material Class.

Material Class	Sample Size	Specific Gravity Mean	Specific Gravity C.V.%	% Volumetric Shrinkage Mean	% Volumetric Shrinkage C.V.%
Live lodgepole	14	.387	5	8.94	14
Dead lodgepole (<5 yrs)	29	.379	7	9.39	16
Dead lodgepole (5+ yrs)	30	.383	8	9.54	13
Lodgepole thinnings	31	.405	9	9.92	13
Live spruce	30	.313	8	9.34	9
Dead spruce	28	.307	6	9.29	13
Spruce-fir thinnings	30	.361	13	9.42	30

analysis of variance showed that there was a significant difference in the specific gravity of the various material classes (see Summary Table 22). The specific gravity of the pine groups was very similar with no one group differing by more than 6 percent from another. This difference could easily be accounted for as a natural variation. It was noted that the specific gravity of the pine thinnings did not differ appreciably from the live pine; however, the spruce thinnings differed considerably from the live spruce. This can be explained by the fact that the pine thinnings came from a relatively young "dog hair" stand; whereas, the spruce thinnings were from suppressed trees of a mature

stand. This also explains the larger variation in both specific gravity and volumetric shrinkage of the spruce thinnings with the degree of variation being caused by the extent of suppression and the rate of growth. An analysis of variance conducted for the percent volumetric shrinkage test showed that there were no significant differences between the material classes. Consequently, the specific gravity and volumetric shrinkage tests do indicate that no fiber degradation took place as a result of beetle-caused mortality.

The nail withdrawal test is summarized in Table 15. The distribution of the data was skewed to the right so that a logarithmic transformation was required to normalize the data. The antilog of each of the material classes gave the actual value. In this test the fir thinnings were separated from the spruce thinnings to distinguish between the species.

Table 15. Nail Withdrawal Load in Kilograms for each Material Class.

Material Class	Sample Size	Nail Withdrawal Load[1] Mean[1] (KG)	C.V.%
Live lodgepole	21	62.2	6
Dead lodgepole (<5 yrs.)	20	60.5	6
Dead lodgepole (5+ yrs.)	20	59.1	6
Lodgepole thinnings	20	81.5	4
Live spruce	20	59.1	5
Dead spruce	20	55.0	6
Spruce thinnings	16	76.9	3
Fir thinnings	4	60.2	3

[1]From a log normal distribution.

This analysis of variance showed that there was a significant difference between the material classes. Further analyses by species with the thinnings removed showed the pine material did not differ in nailholding capacity between the live and dead material. For the spruce there were no differences between the live and dead material in nailholding capacity. Consequently comparing the two species also revealed that they had similar nailholding capacities. The thinning material classes, however, had an average nailholding capacity that was approximately 30 percent higher than all other material classes.

From the same sample, material was cut for the treatability test. Table 16 illustrates the retention of pentachlorophenol in pounds per cubic foot. These results are graphically presented in Figure 12. An analysis of covariance was conducted on the treatability test data. The covariate was the percent sapwood present in the test samples. This analysis determined that there was a significant difference in the

Table 16. Retention of Preservative (Pounds/cubic foot) for each Material Class for Three Treatment Times

Material Class	Sample Size	Treatment-Times-Hours		
		12	24	36
		Retention (lbs/cu. ft)		
Live lodgepole	20	.090	.104	.115
Dead lodgepole (< 5 yrs.)	20	.118	.137	.155
Dead lodgepole (5+ yrs.)	20	.110	.124	.132
Lodgepole thinnings	20	.094	.114	.119
Live spruce	20	.102	.116	.129
Dead spruce	20	.010	.016	.021
Spruce-fir thinnings	20	.030	.042	.045

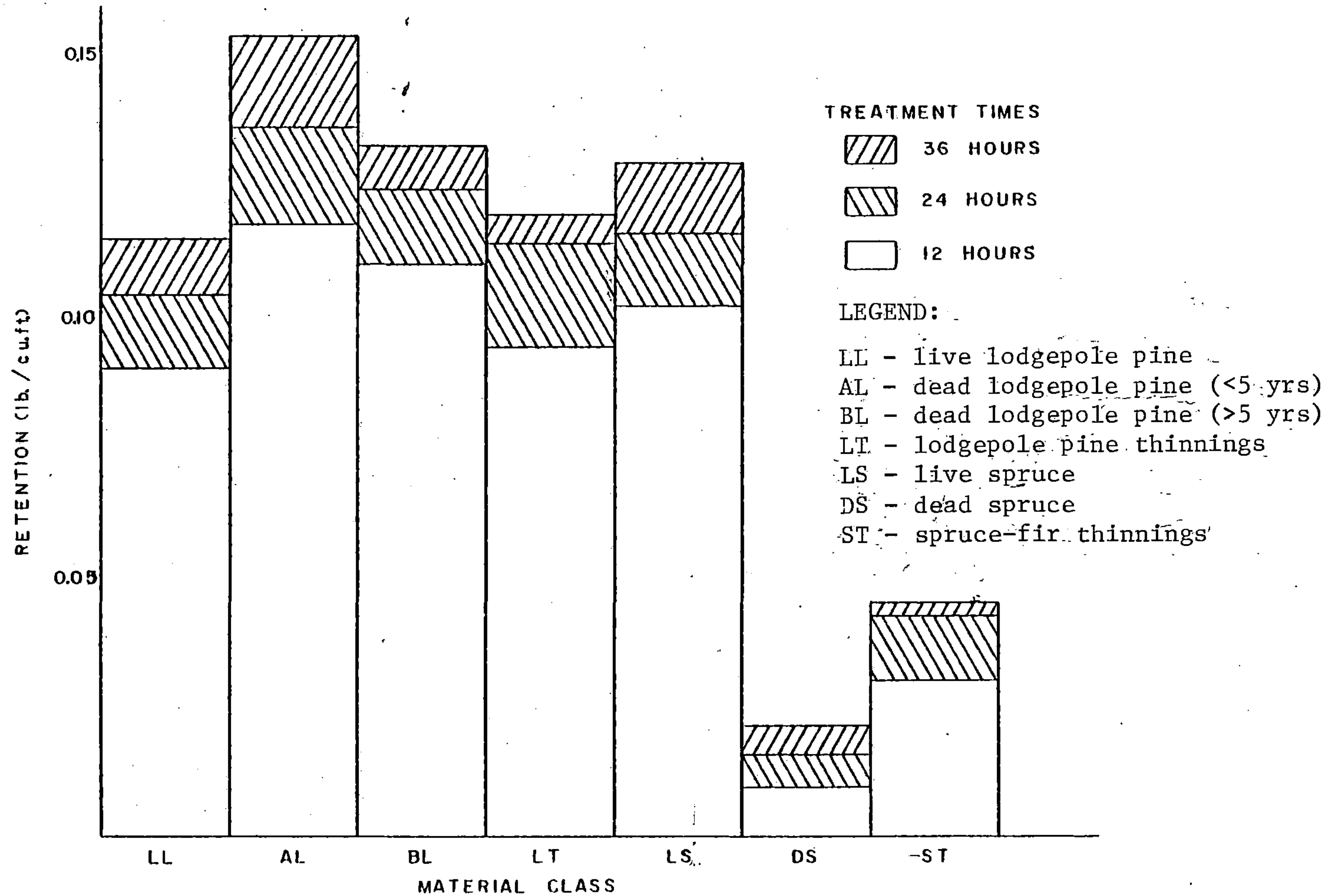

Figure 12. The retention in pounds of pentachlorophenol per cubic foot of material for all material classes.

treatability of the material classes. As was expected, the covariate was also highly significant. The treatment times also had a very significant affect on the retention levels. All the retention levels were below the standard of 0.30 pounds per cubic foot for a non-pressure "penta" treatment of round fence posts. This was expected since the analysis of covariance adjusted the results by removing the variation caused by the different amounts of sapwood and did not adjust to a 100 percent level of exposed sapwood which is the case for roundwood. As can be seen in Figure 12, the recently beetle-killed material had the best retentions and declined the longer the material had been dead. It was theorized that the high retentions were caused by the increased permeability which was due to the presence of the blue-stain fungi and greater number of unaspirated pits. The reason the retentions decreased, the longer the tree had been dead was theorized to be due to aspirating pits as the tree dried on the stump below the fiber saturation point. The aspirated pits block the passageways for the preservative to enter the wood. The differences between the retention levels of the live spruce and the spruce-fir thinnings was attributed to the differences in wood densities.

A multiple comparison analysis was conducted between the retention levels of the different treatment times for each of the material classes. The method selected was Tukey's H.S.D. (honestly significant difference) test. This analysis showed that there was a significant difference between the 12-hour and 36-hour treatment times for all seven material classes. All material classes, except the lodgepole thinnings, the dead spruce, and the spruce-fir thinnings, showed a

significant increase in the retention levels between the 24- and the 36-hour treatment times. Furthermore, all the material classes, except the dead spruce, showed a significant increase in the retention levels between the 12- and the 24-hour treatment times. It should be noted that this method is conservative and the treatment times showed a practical increase in retention levels in all cases except for the 24- to 36-hour treatment period for the spruce thinnings.

For the glue shear block test a two-way analysis of variance was conducted. The factors considered were material class and assembly time. Summary Table 22 depicts this information. A significant difference exists but it is not very strong. When a separate analysis of variance was conducted for each species for material class, no significant differences were found between the live and the dead material. The two closed assembly times (5 and 15 minutes) had no effect on the glue line shear strength. Both assembly times were within the manufacturer's recommended closed assembly time. The moisture content of the glue blocks showed a significant difference; however, the average amoisture contents were within one percent of each other and well within the manufacturer's recommended moisture content range of 6 to 14 percent. The summary of the gluability test is found in Table 17.

Table 18 contains the results of the toughness test. The dead material exhibited a lower toughness value than the live material for each species. The fact that the toughness value for the dead lodgepole pine, dead for 5 years or more, was larger than the toughness value for the dead lodgepole pine, dead for less than 5 years, was attributed to an experimental (sampling) error.

Table 17. Summary of the Glue Shear Block Test for each Material Class.

Material Class	Sample Size	Moisture Content (%)	Glue Shear Strength (Psi) Assembly Times (min) 5	15	Mean	C.V.%
Live lodgepole	20	10.11	1259	1147	1204	13
Dead lodgepole (< 5 years)	20	9.94	1192	1184	1188	16
Dead lodgepole (5+ years)	20	10.09	1279	1230	1237	15
Lodgepole thinnings	20	10.36	1311	1243	1294	14
Live spruce	20	10.95	1047	1161	1105	11
Dead spruce	20	9.05	1093	1180	1132	12
Spruce-fir thinnings	20	9.90	1201	1169	1185	11

Table 18. Summary of Toughness Test for each Material Class.

Material Class	Sample Size	Toughness[1] Mean (in.-lb.)	C.V.%
Live lodgepole	15	102.1	20
Dead lodgepole (< 5 years)	20	84.2	22
Dead lodgepole (5+ years)	17	97.9	25
Lodgepole thinnings	20	125.7	26
Live spruce	21	90.3	27
Dead spruce	21	71.4	48
Spruce thinnings	16	117.2	20
Fir thinnings	4	85.2	24

[1]The radial surface was impacted by an Amsler-type toughness apparatus.

Table 19 illustrates the static bending results for small clear specimens. These results show that the live and dead pine material had similar values for MOE and MOR. Summary Table 22 contains the results of the statistical analyses for verification. The pine thinnings again had higher strength and stiffness values which was attributed to its somewhat higher specific gravity. The live spruce, however, had MOE and MOR values that were below the published values (U.S. Forest Prod. Lab. 1974). These published values were: MOE = 1.30 x 10^6 psi and MOR = 9,300 psi. The differences between the test results and the published values would tend to enforce the belief that the life spruce was not a representative sample.

The analysis of the weatherability specimens consisted of a subjective ranking of the specimens as to the degree of weathering. As was expected, the samples turned gray, the blue-stain color disappeared and any checks present before weathering advanced slightly. Small hairline checks did develop on some of the specimens. In pieces which had a tangential face more checking was observed than in the quartered material. The observations are that no one material class weathered any better or any worse than the rest. All specimens weathered extremely well and the silver-gray coloring of the weathered specimens was aesthetically pleasing. Since all material weathered uniformly, the weatherability test was not used as a key evaluator for the product profiles.

Experiments for the one percent caustic soda solubility test and the hot water extractives test were conducted to measure any fiber degradation. Table 20 tabulates the results of these experiments.

Table 19. Summary of Small Clear Specimen Static Bending Test.[1]

Material Class	Sample Size	% Moisture Content		MOE (x 10^6 psi)		MOR (psi)	
		Mean	C.V.%	Mean	C.V.%	Mean	C.V.%
Live lodgepole	14	11.1	5	1.474	16	10889	13
Dead lodgepole (< 5 years)	16	12.0	6	1.627	19	10961	10
Dead lodgepole (5+ years)	18	10.9	3	1.360	12	10750	12
Lodgepole thinnings	20	10.9	6	2.023	16	12482	14
Live spruce	20	11.0	7	1.140[2]	10	7928[2]	13
Dead spruce	20	12.5	4	.985	14	7502	11
Spruce thinnings	17	12.1	3	1.340	22	10166	15
Fir thinnings	3	11.9	3	1.207	5	9210	12

[1] Each specimen was loaded on the radial surface.

[2] The strength results for live spruce did not correspond to published values in the Wood Handbook (U.S. Forest Prod. Lab. 1974): MOE = 1.30 x 10^6 psi, MOR = 9,300 psi.

Table 20. Summary of the 1% NaOH Solubility and the Hot Water Extractive Tests for each Material Class.

Material Class	1% NaOH Solubility		Hot Water Extractive	
	No. of Trials	Mean %	No. of Trials	Mean %
Live lodgepole	3	10.17	2	7.25
Dead lodgepole (<5 yrs.)	3	8.83	2	7.85
Dead lodgepole (5+ yrs.)	3	9.00	2	6.75
Lodgepole thinnings	3	8.83	2	7.85
Live spruce	3	9.00	2	5.60
Dead spruce	3	7.10	2	5.35
Spruce-fir thinnings	3	8.33	2	6.00

The results of the solubility experiment indicated that no fiber degradation was present. The extractive experiment showed that there was no difference in extractive content within a species. Due to the fact that the ratio of heartwood to sapwood was not controlled in these experiments no definite conclusions could be made on the small differences that occurred between the class of these experiments.

To substantiate the possibility of a greater variation in the dead material classes, a uniformity test was conducted. This consisted of summating the coefficients of variation (C.V.%) of all the tests by material classes. The reciprocal of the average coefficient of variation for each class multiplied by 100 produced the uniformity value for that class. Table 21 shows the results of this test. In this table, the uniformity was slightly lower for the dead lodgepole pine material when compared to the live pine material. The dead spruce

was similar to live spruce in its uniformity. Both, however, were lower than the spruce thinning material. Overall, the average uniformity for all the material classes was fairly high.

Table 21. Uniformity of Tests Results for each Material Class.

Material Class	Average C.V.%	Uniformity[1]
Live lodgepole	16	6.3
Dead lodgepole (<5 years)	24.4 (19.7)[3]	4.1 (5.1)[3]
Dead lodgepole (5+ years)	20.5	4.9
Lodgepole thinnings	16.1	6.2
Live spruce	26.5 (25.6)[3]	3.8 (3.9)[3]
Dead spruce	26.0 (26.4)[3]	4.0 (3.8)[3]
Spruce-fir thinnings[2]	21.3 (20.1)[3]	4.7 (5.0)[3]
Spruce thinnings	15.3	6.5
Fir thinnings	16.5	6.1

[1]Uniformity = 1/C.V.% x 100

[2]Separated when possible

[3]The average C.V.% was calculated after omitting the coefficients of variation containing the outliers (see footnotes 2 and 3 in Table 12).

Summary

The results of this phase of the study revealed that the beetle-killed lodgepole pine material showed no significant loss in stiffness as determined from tests of full size and small clear specimens. The MOR of the full size specimens for the dead material, however, decreased the longer the material had been dead. More checks developed in the dead material the longer the material had been dead. Overall, the dead material maintained much of its integrity with no indication of fiber degradation being observed. The thinning material proved to be superior in almost all properties evaluated over both the live and the dead material.

This study was a product evaluation and not a material evaluation. It did not examine the recovery loss due to using beetle-killed material or the difficulty in manufacturing thinning material (5-7 dbh) into usable 2 x 4 studs. It also did not take into account the economic impact caused by using this material. The economic feasibility of using this material is currently being evaluated by a joint project between the Department of Forest and Wood Sciences at Colorado State University and the Rocky Mountain Forest and Range Experiment Station. Some of the beetle-killed logs were culled due to the presence of rot and defects. Much of the strength reducing decay that would be in a log was removed as slabs and edgings by the very nature of the manufacturing process of making a cant. The studs made from the thinning material contained wane and warp in a single plane.

Table 22. Summary of Analyses of Variance for Each Property.

Properties	F-ratio	Probability Level
	For All Data	
Freedom from Checks	14.66 (6,422 d.f.)	<.005
Freedom from Warp	5.09 (6,422 d.f.)	<.005
Appearance	2.84 (6,165 d.f.)	≅.009
Straightness of Grain	2.00 (7,186 d.f.)	≅.073
Dynamic Modulus of Elasticity (full size)[1]	1.71 (6,165 d.f.) $(21.05)^2$ (6,163 d.f.)	>.250
Modulus of Elasticity (full size)[1]	1.58 (6,165 d.f.) $(9.72)^2$ (6,163 d.f.)	>.250
Modulus of Rupture (full size)[1]	5.77 (6,165 d.f.) $(16.99)^2$ (6,163 d.f.)	<.005
Specific Gravity	40.40 (6,185 d.f.)	<.005
Volumetric Shrinkage	0.80 (6,184 d.f.)	>.250
Nail Withdrawal[1]	6.78 (7,133 d.f.)	<.005
Gluability (Material Class)	2.57 (6,112 d.f.)	<.036
Gluability (Closed Assembly Time)	.03 (2,112 d.f.)	NA
Toughness	8.86 (7,128 d.f.)	<.005
Modulus of Elasticity (small clear)	32.14 (7,120 d.f.)	<.005
Modulus of Rupture	35.26 (7,120 d.f.)	<.005
	For Pine Data	
Modulus of Rupture (full size)[1,3]	2.44 (2,64 d.f.)	<.010
Specific Gravity	4.06 (3,100 d.f.)	<.005
Nailholding[1,3]	.21 (2,58 d.f.)	>.250
Gluability	.98 (3,64 d.f.)	>.250
Toughness[3]	3.48 (2,49 d.f.)	<.050
Modulus of Elasticity (small clear)[3]	5.21 (2,45 d.f.)	<.005
Modulus of Rupture (small clear)	.13 (2,45 d.f.)	>.250

Table 22.--Continued

Properties	F-ratio	Probability Level
	For Spruce Data	
Modulus of Rupture (full size)[1,3]	.02 (1,55 d.f.)	NA
Specific Gravity		
Nailholding[1,3]	.90 (1,38 d.f.)	>.250
Gluability	1.74 (2,48 d.f.)	>.250
Toughness[3]	4.26 (1,40 d.f.)	<.050
Modulus of Elasticity (small clear)[3]	15.08 (1,38 d.f.)	<.005
Modulus of Rupture (small clear)	2.16 (1,38 d.f.)	>.014
	Analysis of Covariance for Treatability Test for All Data	
Material Classes	5.48 (6,132 d.f.)	.005
Covariate (% Sapwood)	11.3 (1,132 d.f.)	.005
Treatment Times	211.8 (2,266 d.f.)	.005

[1]A log normal distribution was used for the analysis.

[2]F-ratio with outlier removed.

[3]With thinning material removed.

Product Evaluation: Product Profiles

Herein the key evaluators that were discussed earlier were used to develop the product profiles. The purpose of the evaluator was to determine the feasibility of using the different classes of material for various products. Table 23 summarizes the key evaluators using the live lodgepole pine class as the standard for comparison.

Following is a display (see Table 24) of how the product profile was determined for "Joists and Studs." In this table the material classes compared were live lodgepole and dead lodgepole that had been dead for less than 5 years. Table 25 tabulates the average index values from the product profiles. Here is relative ranking of the seven material classes for use in fourteen products. The sensitivity of the ranking is somewhat subjective and does not represent a finite quality. The actual end-use of the product and the procurement cost are both important factors that will determine which is the best class of material and is not assessed in this technical feasibility.

For the "Yard Lumber" live lodgepole pine and the lodgepole pine thinnings had the highest index value. The remaining material classes had index values that were fairly similar to each other. For "Joists and Studs" the lodgepole thinnings were superior to the rest of the material classes. This was followed by the live lodgepole pine and the spruce-fir thinning materials. The dead lodgepole pine classes were slightly below the live and dead spruce. The "Mine Timbers" again ranked the lodgepole thinnings the highest. The live lodgepole pine, dead lodgepole pine and spruce-fir thinnings ranked similarly. In this category the live spruce followed by the dead spruce was at the lower end of the scale. All material classes had similar index values for

Table 23. Summary of the Key Evaluators for Product Profile.*

Material Class	Ease of Seasoning[1]	Full Size MOE[2]	Full Size MOR[2]	Straightness of Grain[2]	Appearance[2]	Freedom from Checks[2]
Live lodgepole	100	100	100	100	100	100
Dead Lodgepole (< 5 years)	135.8	88.7	79.1	87.5	91.9	77.6
Dead Lodgepole (5+ years)	148.1	92.3	66.4	83.4	92.5	50.7
Lodgepole thinnings	107.4	116.2	163.3	103.4	71.2	121.4
Live spruce	149.4	49.2[3]	49.6[3]	102.2	87.5	52.0
Dead spruce	200.0	45.8	52.5	93.4	86.0	46.6
Spruce-fir thinnings	111.0	98.0	138.3	93.1	73.6	100.4

*Based on a percentage of the value for live lodgepole.

Table 23.--Continued.

Material Class	Freedom from Warp[2]	Specific Gravity[2]	% Volumetric Shrinkage[2]	Nailholding[2]	Treatability[2] (36 hours)	Glubability[2] (mean assembly time)
Live lodgepole	100	100	100	100	100	100
Dead lodgepole (< 5 years)	87.2	97.9	95.0	97.3	134.8	98.7
Dead lodgepole (5+ years)	95.7	99.0	93.3	95.0	114.8	102.7
Lodgepole thinnings	91.5	104.7	89.0	131.0	103.5	107.5
Live spruce	89.4	80.9	95.5	95.0	112.2[3]	91.8
Dead spruce	110.6	79.3	96.1	88.4	18.3	94.0
Spruce-fir thinnings	84.0	93.3	94.6	118.3	39.1	98.4

Table 23.--Continued.

Material Class	Toughness[2]	Small clear specimens[2] MOE	MOR	Uniformity[5]
Live lodgepole	100	100	100	100
Dead lodgepole (< 5 years)	82	110.4	100.7	65.1 (81.0)[6]
Dead lodgepole (5+ years)	95.9	93.3	98.7	77.8
Lodgepole thinnings	123.1	137.2	114.6	98.4
Live spruce	88.4	77.3[4]	72.8[4]	60.3 (61.9)[6]
Dead spruce	69.9	66.8	68.9	63.5
Spruce-fir thinnings	108.5	89.6	92.0	74.6 (79.4)[6]

[1] $$\text{Ease of Seasoning Evaluator} = \left[\frac{\text{Drying Time of Live Lodgepole} - \text{Drying Time of Other Material}}{\text{Drying Time of Live Lodgepole}} \times 100\right] + 100$$

[2] $$\text{Evaluator} = \frac{\text{Property of One Material Class}}{\text{Same Property of Live Lodgepole}} \times 100$$

[3] Using published values (Bodig 1969) for live Spruce a MOE evaluator of 101.0 and a MOR evaluator of 143.1 are obtained for live spruce.

[4] Using published values (U.S. Forest Prod. Lab 1974) for live spruce a MOE evaluator of 88.2 and a MOR evaluator of 85.4 were obtained.

[5] The uniformity value obtained when the outliers discussed in Table 12 were discarded.

[6] Uniformity results after removing outliers.

Table 24. Example of a Product Profile for Joists and Studs.

Property	Weighting Factor	Live Lodgepole	Dead Lodgepole (<5 yrs.)	
			Evaluator	Weighted Index Value
Seasoned Bending Strength (MOR) (full size specimens)	3	100	79.1	237.3
Seasoned Stiffness (MOE) (full size specimens	3	100	88.7	266.1
Ease of seasoning	1	100	135.8	135.8
Shrinkage	1	100	95.0	95.0
Freedom from warp	3	100	87.2	261.6
Freedom from checks	3	100	77.6	232.8
Nailholding	2	100	97.3	194.6
Uniformity	1	100	65.1	65.1
Index Value	17	1700		1488.3
Average Index Values		100		87.5

Table 25. Summary of Average Index Values for 14 Products by Material Class.

	Live Lodgepole	Dead Lodgepole (<5 yrs.)	Dead Lodgepole (5+ yrs.)	Lodgepole Thinnings	Live Spruce[1]	Dead Spruce	Spruce-fir Thinnings
Yard Lumber (Boards)	100	91.6	89.1	98.0	86.2 (87.1)	90.1	93.6
Joists and Studs	100	87.5	84.5	120.7	73.7 (99.4)	77.6	105.9
Mine Timbers	100	103.0	99.6	122.0	86.4 (113.6)	72.8	98.0
Railroad Ties	100	102.2	100.1	122.8	91.3 (112.1)	75.8	99.3
Houselogs	100	86.2	75.2	98.6	84.0	84.8	90.1
Utility Poles	100	97.2	91.5	112.9	83.1 (103.3)	75.1	91.9
Construction Poles	100	99.3	94.4	132.9	84.4 (107.3)	79.0	95.2
Corral Poles	100	84.9	78.8	117.8	74.0 (94.0)	75.6	103.4
Fence Posts	100	100.6	90.2	129.8	86.5 (106.5)	67.1	101.3
Fencing	100	85.0	79.5	107.8	76.0 (101.4)	78.5	97.1
Paneling (Siding)	100	86.5	82.8	89.6	81.3	83.5	88.3
Pallets	100	87.3	85.6	123.2	74.0 (101.0)	71.5	107.1
Fuelwood	100	113.5	122.1	107.9	118.0	139.8	102.6
Laminated Beams and Joists	100	95.5	90.5	115.7	79.0 (84.0)	77.4	93.2

[1]The values in parenthesis are the index values obtained when published values for MOR and MOE are substituted for the test values.

"Railroad Ties." The exceptions were, however, the lodgepole thinnings which ranked the highest and the dead spruce the lowest. For "Houselogs" the live lodgepole and the lodgepole thinnings graded the highest index values. The remainder of the material classes had similar index values with the exception of the "old" dead lodgepole ordered the lowest.

In the case of "Utility Poles," the longer the material had been dead the less suitable the material. The lodgepole pine on the average was better suited as utility poles than the spruce. Here again, the thinnings had the highest index values for each of the species. "Construction Poles" for pole building construction showed the pine thinnings had a far better index value than the balance of the material groups which had similar index values except for live and dead spruce which were the lowest index values. The lodgepole pine thinning had the highest index value for "Corral Poles." The live lodgepole pine and the spruce thinnings were similar and the longer the beetle-killed material had been dead the less suited it was for corral poles. The live spruce graded low and was similar to dead spruce. All the pine material was well-suited for use as fence posts. The lodgepole pine thinnings had the highest index value of all and the "old" dead lodgepole material had the lowest for the pine. In the case of the spruce thinnings they graded better than the live spruce or the dead spruce which was the lowest.

For "Fencing" the lodgepole thinning material was the best suited. The live lodgepole and the spruce thinnings were similarly suited as fencing. All the dead materials had similar index values and were much less suited for use as this product. The live spruce had the lowest

index value. The live lodgepole was best suited for both interior "Paneling" and exterior "siding." The rest of the material classes had similar index values but they all were less suitable for paneling. For the use of "pallets" it appears the longer the material had been dead the lower the index values. The thinnings had the highest index values so were best suited for use as pallets. The live spruce had an index value that was nearly as poor as the dead spruce which had the lowest index value. For "Fuelwood" the longer the material had been dead the better suited it was for fuelwood. This was due to the lower moisture content of the dead material. For "Laminated Beams and Joists" the lodgepole thinning material showed as the best suited material. The dead lodgepole pine did give a lower index value the longer it had been dead but not seriously so. The spruce material classes all had lower index values than the pine materials and the spruce thinnings should be well-suited for manufacture into laminated products. The live spruce material had an index value similar to the dead spruce material but they were well below the other material classes.

As can be seen in Table 25 and included in this discussion, the live spruce was less suitable than the live lodgepole pine for many of the products considered. These results were unexpected but further reinforced the intuitive feeling that the live spruce sample was not representative of the entire spruce population. From Table 25 it can be seen that by using the published values for MOE and MOR for Engelmann spruce the live spruce behaves more as would be expected for the species throughout its range.

This study demonstrated the technical feasibility of using beetle-killed material and thinning material in a variety of products. The overall observation and summary leads to the conclusion that beetle-killed material can compete technically with the live material.

CHAPTER V

CONCLUSION

This project evaluated the technical feasibility of using timber that would be removed during a salvage or cleanup operation of a beetle infested stand. This material includes the beetle-killed material and the thinnings that would be removed to yield a more vigorous stand. The economic impact of conducting these salvage operations or of trying to market this material was not evaluated here.

The results of the property evaluation revealed that the beetle-killed material had no fiber degradation. Most of the loss of value of this material resulted from drying defects that occurred when the logs dried on the stump. The thinning material had outstanding results in most all properties evaluaated. It did have a high occurrence of warp and wane present.

From the results of the product profiles it can be seen that the dead-tree material did decrease in product feasibility the longer it had been dead. The beetle-killed lodgepole that had been dead less than 5 years showed very little change in index values as compared to the live lodgepole. The lodgepole pine that had been dead for 5 or more years showed a somewhat lower feasibility for many of the products. The dead spruce showed a significant drop in the average index values for most all of the properties. This was somewhat expected since it had been dead for twenty to twenty-five years. Both the lodgepole and the

spruce-fir thinnings had as good or superior index ratings as the live lodgepole pine material which was used as a standard in this study. The live spruce material showed abnormally low product feasibility ratings, the occurrence of which was concluded to be due to the live spruce material not being a representative sample of typical spruce timber in Colorado and Wyoming.

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APPENDICES

APPENDIX A

FULL SIZE BENDING TESTS

Appendix A

TEST FOR NORMALITY

(HISTOGRAMS)

```
HIST ED FOR LIVE LODGEPOLE C6

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
         1.0         2      **
         1.2         4      ****
         1.4         3      ***
         1.6         3      ***
         1.8         0
         2.0         2      **
         2.2         1      *

--
? HIST ED FOR DEAD PINE (LESS THAN FIVE YRS.)C9

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
          .8         1      *
         1.0         6      ******
         1.2         7      *******
         1.4         5      *****
         1.6         4      ****
         1.8         3      ***
         2.0         1      *
         2.2         1      *

--
? HIST ED FOR DEAD PINE (OVER FIVE YRS.) C17

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
         1.0         5      *****
         1.1         0
         1.2         5      *****
         1.3         6      ******
         1.4         3      ***
         1.5         0
         1.6         1      *
         1.7         3      ***
         1.8         0
         1.9         0
         2.0         1      *

--
? HIST ED FOR PINE THINNINGS C20

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
         1.1         2      **
         1.2         0
         1.3         1      *
         1.4         0
         1.5         4      ****
         1.6         7      *******
         1.7         3      ***
         1.8         2      **
         1.9         4      ****
         2.0         2      **
         2.1         0
         2.2         1      *
         2.3         1      *

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  HIST ED FOR LIVE SPRUCE C23

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
         0.0        1       *
          .2        0
          .4        0
          .6        0
          .8        1       *
         1.0       10       **********
         1.2        9       *********
         1.4        6       ******

 --
? HIST ED FOR DEAD SPRUCE C26

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
         0.0        1       *
          .1        0
          .2        0
          .3        0
          .4        0
          .5        0
          .6        0
          .7        1       *
          .8        2       **
          .9        8       ********
         1.0        9       *********
         1.1        6       ******
         1.2        3       ***

 --
? HIST ED FOR SPRUCE THINNINGS C29

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
          .8        1       *
          .9        1       *
         1.0        4       ****
         1.1        1       *
         1.2        3       ***
         1.3        3       ***
         1.4        3       ***
         1.5        3       ***
         1.6        1       *
         1.7        0
         1.8        1       *

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```
HIST MOE FOR LIVE PINE C7

  MIDDLE OF    NUMBER OF
  INTERVAL     OBSERVATIONS
        .6         1       *
        .8         1       *
       1.0         1       *
       1.2         4       ****
       1.4         4       ****
       1.6         1       *
       1.8         1       *
       2.0         2       **

--
? HIST MOE FOR DEAD PINE (LESS THAN FIVE YRS.) C10

  MIDDLE OF    NUMBER OF
  INTERVAL     OBSERVATIONS
        .7         1       *
        .8         1       *
        .9         4       ****
       1.0         6       ******
       1.1         3       ***
       1.2         4       ****
       1.3         4       ****
       1.4         1       *
       1.5         0
       1.6         1       *
       1.7         2       **
       1.8         1       *

--
? HIST MOE FOR DEAD PINE (OVER FIVE YRS.)C18

  MIDDLE OF    NUMBER OF
  INTERVAL     OBSERVATIONS
        .8         1       *
        .9         3       ***
       1.0         5       *****
       1.1         2       **
       1.2         6       ******
       1.3         1       *
       1.4         1       *
       1.5         2       **
       1.6         2       **
       1.7         0
       1.8         0
       1.9         1       *

--
? HIST MOE FOR PINE THINNINGS C21

  MIDDLE OF    NUMBER OF
  INTERVAL     OBSERVATIONS
        .6         2       **
        .8         2       **
       1.0         0
       1.2         2       **
       1.4         3       ***
       1.6         9       *********
       1.8         3       ***
       2.0         4       ****
       2.2         0
       2.4         2       **

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```

?

HIST MOE FOR LIVE SPRUCE C24

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	1	*
.2	0	
.4	0	
.6	0	
.8	4	****
1.0	12	************
1.2	9	*********
1.4	1	*

--

? HIST MOE FOR DEAD SPRUCE C27

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
0.0	1	*
.1	0	
.2	0	
.3	0	
.4	1	*
.5	0	
.6	0	
.7	0	
.8	5	*****
.9	9	*********
1.0	8	********
1.1	5	*****
1.2	1	*

--

? HIST MOE FOR SPRUCE THINNINGS C30

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
.4	1	*
.6	0	
.8	1	*
1.0	1	*
1.2	9	*********
1.4	5	*****
1.6	2	**
1.8	2	**

--

```
HIST MOR LIVE PINE C8

MIDDLE OF    NUMBER OF
INTERVAL     OBSERVATIONS
  1000.        1     *
  2000.        2     **
  3000.        2     **
  4000.        4     ****
  5000.        1     *
  6000.        0
  7000.        1     *
  8000.        0
  9000.        2     **
 10000.        0
 11000.        2     **

--
? HIST MOR DEAD PINE (LESS THAN FIVE YRS.) C16

MIDDLE OF    NUMBER OF
INTERVAL     OBSERVATIONS
  1000.        2     **
  2000.        3     ***
  3000.        9     *********
  4000.        5     *****
  5000.        5     *****
  6000.        1     *
  7000.        1     *
  8000.        1     *
  9000.        1     *

--
? HIST MOR DEAD PINE (OVER FIVE YRS.) C19

MIDDLE OF    NUMBER OF
INTERVAL     OBSERVATIONS
   500.        1     *
  1000.        0
  1500.        1     *
  2000.        3     ***
  2500.        3     ***
  3000.        2     **
  3500.        6     ******
  4000.        2     **
  4500.        2     **
  5000.        1     *
  5500.        3     ***

--
? HIST MOR PINE THINNINGS C22

MIDDLE OF    NUMBER OF
INTERVAL     OBSERVATIONS
  4000.        3     ***
  5000.        2     **
  6000.        3     ***
  7000.        6     ******
  8000.        3     ***
  9000.        3     ***
 10000.        4     ****
 11000.        3     ***

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```
 HIST MOR FOR LIVE SPRUCE C25

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
        0.         1      *
     1000.         3      ***
     2000.         5      *****
     3000.         7      *******
     4000.         8      ********
     5000.         2      **
     6000.         1      *

--
? HIST MOR FOR DEAD SPRUCE C28

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
        0.         1      *
     1000.         1      *
     2000.         8      ********
     3000.        10      **********
     4000.         6      ******
     5000.         3      ***
     6000.         0
     7000.         1      *

--
? HIST MOR FOR SPRUCE THINNINGS C31

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
     3000.         2      **
     4000.         1      *
     5000.         3      ***
     6000.         5      *****
     7000.         4      ****
     8000.         3      ***
     9000.         2      **
    10000.         0
    11000.         1      *

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?
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RESULTS OF FULL SIZE BENDING TESTS

COLUMN 1 = MATERIAL CLASSES (1 = LIVE LODGEPOLE, 2 = DEAD LODGEPOLE (5YRS.
3 = DEAD LODGEPOLE 5+ YRS, 4 = LODGEPOLE THINNINGS, 5 = LIVE
SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE-FIR THINNINGS)

COLUMN 2 = DYNAMIC MODULUS OF ELASTICITY (*1000000 PSI)

COLUMN 3 = STATIC MODULUS OF ELASTICITY (*1000000 PSI)

COLUMN 4 = MODULUS OF RUPTURE (PSI)

COLUMN 5 = LUMBER GRADES- LIGHT FRAMING (1 = CONSTRUCTION, 2 = STANDARD,
3 = UTILITY, 4 = ECONOMY, 0 = CULL)

COLUMN 6 = %MOISTURE CONTENT

COLUMN 7 = SPECIFIC GRAVITY

1	1.271	1.331	3758.	2.	7.02	.362	1
1	2.219	1.999	4182.	2.	7.37	.407	2
1	1.514	1.388	3941.	3.	7.69	.411	3
1	1.119	.986	2768.	1.	7.37	.387	4
1	1.163	1.102	4565.	1.	7.97	.390	5
1	1.915	1.925	10920.	4.	4.60	.382	6
1	1.558	1.519	8892.	4.	7.54	.396	7
1	1.317	1.228	2490.	2.	7.62	.367	8
1	.940	.643	2444.	2.	7.19	.366	9
1	1.071	1.230	4232.	3.	7.67	.396	10
1	1.355	1.235	2575.	3.	7.62	.362	11
1	2.016	1.871	11174.	3.	7.63	.414	12
1	1.501	1.455	3465.	4.	7.10	.377	13
1	1.363	1.371	6718.	2.	8.01	.414	14
1	1.130	.780	1470.	2.	8.09	.373	15
2	1.073	.973	4867.	1.	7.26	.371	16
2	1.034	1.021	4351.	0.	7.32	.417	17
2	1.325	1.058	1313.	2.	6.64	.385	18
2	1.116	.890	2224.	2.	6.65	.367	19
2	1.218	1.063	3276.	3.	5.11	.344	20
2	2.028	1.799	5647.	3.	7.01	.389	21
2	1.407	1.009	2960.	3.	7.10	.391	22
2	1.297	.915	1077.	2.	7.20	.341	23
2	1.427	1.161	2529.	2.	6.33	.346	24
2	1.292	1.014	2644.	2.	6.03	.388	25
2	1.546	1.259	3226.	3.	7.30	.385	26
2	1.036	.776	1852.	2.	7.25	.351	27
2	.835	.726	3279.	1.	7.12	.345	28

2	1.541	1.348	5237.	2.	7.36	.393	29
2	2.298	1.714	5199.	2.	7.12	.415	30
2	1.141	1.038	3531.	2.	7.23	.337	31
2	1.580	1.273	4010.	4.	7.13	.364	32
2	1.758	1.606	8148.	4.	7.18	.354	33
2	1.046	.888	3204.	1.	50.20	.407	34
2	1.745	1.269	3154.	3.	7.10	.385	35
2	1.645	1.449	6750.	3.	6.84	.371	36
2	1.718	1.662	9366.	2.	7.64	.385	37
2	1.389	1.159	4582.	2.	7.06	.434	38
2	1.191	1.181	5262.	1.	7.32	.372	39
2	1.289	1.122	3098.	2.	7.57	.428	40
2	1.060	.960	3772.	3.	6.67	.350	41
2	1.331	1.227	2159.	2.	7.36	.410	42
2	1.040	.910	3682.	1.	6.94	.389	43
3	1.655	1.502	3997.	2.	7.19	.370	44
3	1.043	1.006	3469.	4.	6.22	.323	45
3	1.338	1.189	4481.	3.	7.44	.355	46
3	1.206	1.072	2758.	2.	6.43	.381	47
3	.995	.911	2548.	2.	6.68	.347	48
3	1.213	1.027	2339.	2.	6.38	.352	49
3	1.591	1.440	3372.	2.	6.36	.424	51
3	1.425	1.249	3690.	2.	6.77	.372	50
3	1.334	1.151	2247.	2.	6.74	.370	52
3	1.203	1.237	5324.	2.	7.39	.428	53
3	.973	.909	1848.	2.	7.62	.321	54
3	1.343	1.199	3722.	2.	6.57	.362	55
3	1.162	.801	1302.	1.	6.81	.368	56
3	1.419	1.340	5344.	4.	7.49	.392	57
3	1.025	1.003	2295.	1.	7.73	.394	58
3	1.334	.941	2029.	2.	7.26	.393	59
3	1.995	1.919	5550.	3.	6.86	.407	60
3	1.444	1.223	3110.	2.	6.62	.395	61
3	.974	.984	4010.	2.	6.33	.392	62
3	1.150	1.570	305.	2.	6.23	.378	63
3	1.703	1.631	4706.	2.	7.04	.380	64
3	1.310	1.017	3739.	2.	7.36	.414	65
3	1.652	1.481	5127.	3.	6.98	.370	66
3	1.346	1.149	3626.	2.	6.10	.413	67
4	1.584	1.825	10314.	3.	7.30	.456	68
4	1.554	1.153	4278.	2.	8.26	.389	69
4	1.127	2.300	3662.	0.	6.86	.442	70
4	2.151	.820	10688.	3.	7.28	.402	71
4	1.874	.805	6868.	2.	7.34	.394	72
4	1.574	1.664	8348.	3.	6.89	.357	73
4	1.251	1.399	4072.	2.	6.48	.408	74
4	1.456	1.602	7892.	2.	6.84	.374	75
4	1.835	1.681	7555.	3.	7.29	.443	76
4	1.565	.650	7070.	2.	5.98	.355	77
4	1.938	1.567	5996.	1.	6.97	.422	78
4	1.517	1.720	8646.	0.	7.28	.389	79
4	1.670	.687	7110.	2.	7.04	.360	80
4	2.964	2.964	7109.	0.	7.84	[illegible]	81
4	1.550	1.508	9494.	1.	7.07	.336	82
4	1.096	1.200	5637.	0.	7.22	.409	83
4	1.603	1.638	7396.	0.	7.49	.413	84
4	1.688	1.614	5014.	0.	7.28	.398	85

4	1.981	2.098	10314.	3.	7.11	.478	86
4	1.877	1.976	10394.	1.	6.43	.419	87
4	1.807	1.862	8970.	2.	6.96	.419	88
4	2.037	1.916	9730.	1.	7.02	.426	89
4	1.520	1.361	7142.	1.	7.16	.398	90
4	1.684	1.551	6350.	1.	7.14	.371	91
4	1.623	1.664	10706.	2.	7.88	.457	92
4	1.918	2.066	11040.	2.	7.34	.433	93
4	1.536	1.470	4739.	1.	7.30	.372	94
5	.997	.950	1917.	3.	6.07	.299	95
5	1.141	.994	3703.	2.	6.04	.305	96
5	1.131	1.039	4382.	3.	6.62	.325	97
5	0.000	0.000	0.	0.	6.62	.306	98
5	.997	.930	2289.	3.	5.56	.309	99
5	1.168	1.159	4420.	2.	6.12	.313	100
5	.980	.809	2217.	2.	3.87	.314	101
5	1.050	.888	3106.	3.	6.23	.319	102
5	1.050	1.107	1178.	2.	6.12	.298	103
5	1.089	.982	4662.	0.	6.05	.291	104
5	1.043	.982	3101.	2.	6.42	.296	105
5	1.435	1.199	2642.	2.	5.59	.299	106
5	1.047	.951	3926.	2.	5.92	.339	107
5	1.149	1.098	3515.	2.	6.16	.310	108
5	1.113	1.012	2304.	3.	6.09	.288	109
5	.923	.825	1411.	2.	4.92	.305	110
5	1.274	1.220	3487.	3.	5.64	.304	111
5	.881	.944	3779.	2.	5.99	.304	112
5	1.137	.984	1977.	0.	6.87	.419	113
5	1.309	1.128	2970.	3.	5.71	.294	114
5	1.190	.992	4073.	1.	6.75	.343	115
5	1.257	1.114	3439.	3.	5.18	.290	116
5	1.499	1.400	6480.	2.	5.54	.290	117
5	1.301	1.299	5478.	1.	6.18	.305	118
5	1.325	1.297	3940.	2.	6.98	.342	119
5	1.019	.948	1196.	2.	5.28	.314	120
6	.979	.971	3070.	2.	6.55	.314	122
5	1.431	1.288	2863.	4.	6.21	.301	121
6	1.061	1.103	4493.	2.	6.32	.317	123
6	1.209	1.043	3226.	4.	6.12	.300	124
6	1.025	1.098	4836.	1.	5.10	.287	125
6	.944	.846	3142.	1.	5.40	.298	126
6	0.000	0.000	0.	0.	6.31	.366	127
6	1.084	.897	3807.	2.	5.73	.287	128
6	1.166	.430	2858.	2.	6.29	.301	129
6	.891	.957	2438.	2.	6.91	.304	130
6	.720	.787	1358.	2.	6.07	.289	131
6	1.006	.962	3744.	1.	6.32	.320	132
6	1.064	1.064	1622.	2.	5.47	.283	133
6	.997	.864	2417.	2.	6.12	.304	134
6	.787	.863	2158.	1.	6.34	.339	135
6	1.084	.962	1946.	1.	6.45	.319	136
6	1.18[illegible]	1.120	[illegible]	2.	6.0[illegible]	.307	137
6	.954	.941	4404.	3.	5.11	.305	138
6	.939	.918	3928.	2.	5.31	.301	139
6	.881	.833	2322.	1.	5.83	.297	140
6	.974	.926	3062.	2.	4.84	.285	141

6	.871	.919	3636.	3.	6.66	.292	142
6	.923	.844	2597.	1.	5.82	.291	143
6	1.018	1.135	6567.	2.	6.11	.307	144
6	1.146	1.153	5318.	4.	6.69	.310	145
6	.988	1.018	2928.	2.	5.81	.306	146
6	1.106	.997	2426.	4.	6.23	.303	147
6	.906	.822	2212.	2.	5.83	.290	148
6	.849	.887	2718.	2.	7.03	.349	149
6	.953	.926	3311.	2.	6.11	.307	150
7	1.206	1.184	7202.	0.	6.52	.325	152
6	.974	.954	3233.	1.	7.45	.325	151
7	1.290	1.294	5620.	0.	22.79	.301	153
7	1.038	1.169	5506.	1.	6.32	.318	154
7	1.106	.449	6696.	2.	7.31	.347	155
7	1.314	1.295	8392.	1.	7.19	.390	156
7	1.542	1.452	7914.	2.	7.59	.349	157
7	1.760	1.799	5435.	4.	7.76	.395	158
7	1.464	1.540	7623.	3.	7.65	.379	159
7	1.642	1.875	10776.	3.	6.70	.391	160
7	1.406	1.403	8558.	2.	7.24	.361	161
7	.829	.834	2911.	1.	6.50	.298	162
7	1.254	1.284	5870.	2.	6.77	.335	163
7	1.019	1.112	5496.	0.	7.45	.303	164
7	.892	1.394	6286.	1.	11.94	.360	165
7	1.040	1.226	6642.	0.	7.67	.406	166
7	1.400	1.484	5554.	1.	7.25	.427	167
7	.973	.988	3485.	4.	6.86	.306	168
7	1.236	1.176	5201.	1.	7.30	.298	169
7	1.423	1.464	4311.	2.	7.10	.363	170
7	1.211	1.240	6822.	2.	6.98	.369	171
7	1.487	1.504	9266.	2.	6.04	.354	172

SUMMARY TABLE FOR FULL SIZE SPECIMEN BENDING TESTS

	Moisture Content		Specific Gravity		Dynamic E			M O E			M O R		
	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	%C.V.	Mean	St.Dev.	%C.V.	Mean	St.Dev.	%C.V.
Live Lodgepole	7.37	.859	.387	.0197	1.430	.369	25.8	1.337	.339	25.6	5306	3223	60.7
Dead Lodgepole(5 yrs.)	8.47	8.040	.379	.0275	1.369	.333	24.3	1.160	.279	24.1	3952	1901	48.1
Dead Lodgepole(5+ yrs.)	6.90	.513	.383	.0308	1.326	.258	19.5	1.206	.271	22.5	3373	1355	40.2
Lodgepole Thinnings	7.11	.418	.405	.0379	1.677	.281	16.8	1.559	.450	28.9	7649	2224	29.1
Live Spruce	6.61	3.730	.313	.0260	1.109	.272	24.5	1.018	.257	25.2	3129	1405	44.9
Dead Spruce(20-25 yrs.)	6.11	.595	.307	.0196	.953	.214	22.5	.908	.220	24.2	3159	1301	41.2
Spruce-fir Thinnings	7.80	3.00	.361	.0454	1.263	.248	19.6	1.294	.309	23.8	6470	1882	29.1

LEVELS: 1 = LIVE LODGEPOLE, 2 = DEAD LODGEPOLE (5< YRS.), 3 = DEAD LODGEPOLE (5+ YRS.), 4 = LODGEPOLE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE-FIR THINNINGS

```
ONEW LOG DYNAMIC E FOR FULL SIZE SPECIMENS FOR ALL DATA C22 C1

 ANALYSIS OF VARIANCE

 DUE TO          DF          SS        MS=SS/DF       F-RATIO
 FACTOR           6        23.44          3.91          1.71
 ERROR          165       376.88          2.28
 TOTAL          171       400.31

 LEVEL          N          MEAN         ST. DEV.
 1             15         14.14            .25
 2             28         14.10            .23
 3             24         14.08            .19
 4             27         14.32            .17
 5             27         13.43           2.69
 6             30         13.33           2.52
 7             21         14.03            .20

 POOLED ST. DEV. =          1.51

 INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
 (BASED ON POOLED STANDARD DEVIATION)
        +---------+---------+---------+---------+---------+---------+
 1                     I***************I**************I
 2                         I**********I**********I
 3                       I***********I***********I
 4                               I**********I***********I
 5               I***********I**********I
 6              I*********I**********I
 7                      I************I************I
        +---------+---------+---------+---------+---------+---------+
      12.50     13.00     13.50     14.00     14.50     15.00     15.50

 --
```

```
ONEW LOG MOE FOR FULL SIZE SPECIMENS FOR ALL DATA C23 C1

 ANALYSIS OF VARIANCE

 DUE TO          DF          SS        MS=SS/DF        F-RATIO
 FACTOR           6       21.65           3.61           1.58
 ERROR          165      377.69           2.29
 TOTAL          171      399.34


 LEVEL          N          MEAN         ST. DEV.
 1             15         14.06             .31
 2             28         13.94             .23
 3             24         13.98             .22
 4             27         14.21             .34
 5             27         13.35            2.67
 6             30         13.28            2.51
 7             21         14.04             .30

 POOLED ST. DEV. =          1.51

 INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
 (BASED ON POOLED STANDARD DEVIATION)
        +---------+---------+---------+---------+---------+---------+
 1                   I****************I****************I
 2                     I***********I************I
 3                     I************I*************I
 4                           I************I***********I
 5        I***********I************I
 6       I***********I***********I
 7                     I**************I*************I
        +---------+---------+---------+---------+---------+---------+
     12.70     13.15     13.60     14.05     14.50     14.95     15.40
```

ONEW LOG MOR FOR FULL SIZE SPECIMENS FOR ALL DATA C24 C1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	32.989	5.498	5.77
ERROR	165	157.177	.953	
TOTAL	171	190.165		

LEVEL	N	MEAN	ST. DEV.
1	15	8.407	.605
2	28	8.172	.490
3	24	7.998	.613
4	27	8.897	.318
5	27	7.7[illegible]	.598
6	30	7.4[illegible]	.508
7	21	8.731	.[illegible]11

POOLED ST. DEV. = .976

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
1                      I***********I************I
2                   I********I********I
3               I*********I*********I
4                                     I********I*********I
5         I*********I********I
6           I********I********I
7                                I*********I**********I
        +---------+---------+---------+---------+---------+---------+
      7.20      7.60      8.00      8.40      8.80      9.20      9.60
```

--

ONEW LOG ED FOR FULL SIZE SPECIMENS FOR PINE DATA C32 C30

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	.9189	.3063	7.02
ERROR	90	3.9267	.0436	
TOTAL	93	4.8457		

LEVEL	N	MEAN	ST. DEV.
1	15	14.144	.245
2	28	14.103	.233
3	24	14.080	.190
4	27	14.318	.175

POOLED ST. DEV. = .209

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1                I***********I***********I
2              I********I********I
3           I********I*********I
4                                         I********I********I
       +---------+---------+---------+---------+---------+---------+
    13.950    14.040    14.130    14.220    14.310    14.400    14.490
```

--

? ONEW LOG ED FOR FULL SIZE SPECIMENS FOR PINE WITH THINNINGS REMOVED C

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	.0379	.0189	.39
ERROR	64	3.1329	.0490	
TOTAL	66	3.1708		

LEVEL	N	MEAN	ST. DEV.
1	15	14.144	.245
2	28	14.103	.233
3	24	14.080	.190

POOLED ST. DEV. = .221

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1                I******************I******************I
2               I*************I*************I
3          I***************I***************I
       +---------+---------+---------+---------+---------+---------+
    13.981    14.040    14.100    14.160    14.220    14.280    14.340
```

--

ONEW LOG MOE FOR FULL SIZE SPECIMENS FOR PINE DATA C33 C30

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	1.1628	.3876	5.01
ERROR	90	6.9619	.0774	
TOTAL	93	8.1247		

LEVEL	N	MEAN	ST. DEV.
1	15	14.063	.314
2	28	13.937	.232
3	24	13.980	.216
4	27	14.210	.344

POOLED ST. DEV. = .278

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
1                   I*************I**************I
2          I**********I*********I
3              I**********I**********I
4                                 I**********I**********I
        +---------+---------+---------+---------+---------+---------+
      13.80     13.90     14.00     14.10     14.20     14.30     14.40
```

--

ONEW LOG MOE FOR FULL SIZE SPECIMENS FOR PINE WITH TINNINGS REMOVED

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	.1539	.0769	1.26
ERROR	64	3.8935	.0608	
TOTAL	66	4.0474		

LEVEL	N	MEAN	ST. DEV.
1	15	14.063	.314
2	28	13.937	.232
3	24	13.980	.216

POOLED ST. DEV. = .247

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
1                   I***************I***************I
2        I**********I***********I
3            I************I***********I
        +---------+---------+---------+---------+---------+---------+
      13.840    13.980    14.000    14.080    14.160    14.240    14.320
```

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?

? ONEW LOG MOR FOR FULL SIZE SPECIMENS FOR PINE DATA C34 C30

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	11.920	3.973	15.62
ERROR	90	22.892	.254	
TOTAL	93	34.811		

LEVEL	N	MEAN	ST. DEV.
1	15	8.407	.605
2	28	8.172	.490
3	24	7.998	.613
4	27	8.897	.318

POOLED ST. DEV. = .504

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
1                   I*******I*********I
2             I*****I******I
3       I******I*****I
4                                     I******I*****I
        +---------+---------+---------+---------+---------+---------+
      7.80      8.10      8.40      8.70      9.00      9.30      9.60
```

ONEW MOR FOR FULL SIZE SPECIMENS FOR PINE DATA WITH THINNINGS REMOVED

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	1.547	.774	2.44
ERROR	64	20.255	.316	
TOTAL	66	21.802		

LEVEL	N	MEAN	ST. DEV.
1	15	8.407	.605
2	28	8.172	.490
3	24	7.998	.613

POOLED ST. DEV. = .563

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
1                                 I*************I**************I
2                         I**********I*********I
3               I***********I**********I
        +---------+---------+---------+---------+---------+---------+
      7.60      7.80      8.00      8.20      8.40      8.60      8.80
```

ONEW LOG ED FOR FULL SIZE SPECIMENS FOR SPRUCE C32 C30

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	6.63	3.31	.67
ERROR	75	372.95	4.97	
TOTAL	77	379.57		

LEVEL	N	MEAN	ST. DEV.
5	27	13.43	2.69
6	30	13.33	2.52
7	21	14.03	.20

POOLED ST. DEV. = 2.23

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
         +---------+---------+---------+---------+---------+---------+
5          I****************I****************I
6        I****************I****************I
7                  I*****************I*****************I
         +---------+---------+---------+---------+---------+---------+
       12.50     13.00     13.50     14.00     14.50     15.00     15.50
```

ONEW LOG MOE FOR FULL SIZE SPECIMENS FOR SPRUCE C33 C30

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	8.12	4.06	.82
ERROR	75	370.73	4.94	
TOTAL	77	378.85		

LEVEL	N	MEAN	ST. DEV.
5	27	13.35	2.67
6	30	13.28	2.51
7	21	14.04	.30

POOLED ST. DEV. = 2.22

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
         +---------+---------+---------+---------+---------+---------+
5               I**************I**************I
6               I*************I*************I
7                        I****************I****************I
         +---------+---------+---------+---------+---------+---------+
       12.00     12.60     13.20     13.80     14.40     15.00     15.60
```

ONEW LOG MOR FOR FULL SIZE SPECIMENS FOR SPRUCE C34 C30

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	15.25	7.63	4.26
ERROR	75	134.28	1.79	
TOTAL	77	149.54		

LEVEL	N	MEAN	ST. DEV.
5	27	7.71	1.60
6	30	7.76	1.51
7	21	8.73	.31

POOLED ST. DEV. = 1.34

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
 5          I*********I*********I
 6            I*********I*********I
 7                             I***********I***********I
        +---------+---------+---------+---------+---------+---------+
      7.00      7.50      8.00      8.50      9.00      9.50     10.00
```

ONEW LOG MOR FOR FULL SIZE SPECIMENS FOR SPRUCE WITH THINNINGS REMOVED

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	1	.05	.05	.02
ERROR	55	132.35	2.41	
TOTAL	56	132.40		

LEVEL	N	MEAN	ST. DEV.
5	27	7.71	1.60
6	30	7.76	1.51

POOLED ST. DEV. = 1.55

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
 5      I***********************I***********************I
 6          I**********************I**********************I
        +---------+---------+---------+---------+---------+---------+
      7.10      7.35      7.60      7.85      8.10      8.35      8.60
```

--

? ONEW EM FOR FULL SIZE BENDING TEST FOR ALL DATA WITH OUTLIERS REMOVED

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	4.3560	.7260	21.05
ERROR	163	5.6215	.0345	
TOTAL	169	9.9775		

LEVEL	N	MEAN	ST. DEV.
1	15	14.144	.245
2	28	14.103	.233
3	24	14.080	.190
4	27	14.318	.175
5	26	13.947	.138
6	29	13.794	.121
7	21	14.030	.201

POOLED ST. DEV. = .186

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1                            I******I*****I
2                           I****I***I
3                         I****I****I
4                                         I***I****I
5                 I***I****I
6        I***I****I
7                      I****I****I
       +---------+---------+---------+---------+---------+---------+
    13.70     13.85     14.00     14.15     14.30     14.45     14.60
```

--

? ONEW MOE FOR FULL SIZE BENDING TEST FOR ALL DATA WITH OUTLIER REMOVED

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	3.6521	.6087	9.72
ERROR	163	10.2032	.0626	
TOTAL	169	13.8553		

LEVEL	N	MEAN	ST. DEV.
1	15	14.063	.314
2	28	13.937	.232
3	24	13.980	.216
4	27	14.210	.344
5	26	13.861	.148
6	29	13.740	.181
7	21	14.037	.298

POOLED ST. DEV. = .250

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
1                               I********I*******I
2                         I*****I*******I
3                            I*****I******I
4                                           I******I*****I
5                   I*****I******I
6           I*****I*****I
7                               I******I******I
        +---------+---------+---------+---------+---------+---------+
      13.60     13.75     13.90     14.05     14.20     14.35     14.50
```

? ONEW MOR FOR FULL SIZE BENDING TEST FOR ALL DATA WITH OUTLIERS REMOVED

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	20.740	3.457	16.99
ERROR	163	33.167	.203	
TOTAL	169	53.909		

LEVEL	N	MEAN	ST. DEV.
1	15	8.407	.605
2	28	8.172	.490
3	24	7.993	.613
4	27	8.897	.312
5	26	8.004	.437
6	29	8.041	.357
7	21	8.731	.311

POOLED ST. DEV. = .451

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1                        I********I********I
2                 I*******I*******I
3        I*******I*******I
4                                              I*******I*******I
5        I*******I*******I
6          I******I*******I
7                                      I********I********I
       +---------+---------+---------+---------+---------+---------+
     7.80      8.05      8.30      8.55      8.80      9.05      9.30
```

APPENDIX B

SMALL CLEAR BENDING TEST

LEVELS: 1 = LIVE LODGEPOLE, 2 = DEAD LODGEPOLE (5< YRS.), 3 = DEAD LODGEPOLE (5+ YRS.), 4 = LODGEPOLE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE THINNINGS, 8 = FIR THINNINGS

? ONEW %MC FOR SMALL CLEAR BENDING TESTS ROUNDED TO NEAREST INTERGER

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	55.081	9.180	27.53
ERROR	127	42.351	.333	
TOTAL	133	97.433		

LEVEL	N	MEAN	ST. DEV.
1	14	11.143	.535
2	19	12.000	.745
3	21	10.905	.301
4	20	10.900	.641
5	20	11.000	.795
6	21	12.524	.512
7	19	12.105	.315

POOLED ST. DEV. = .577

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
        +---------+---------+---------+---------+---------+---------+
1             I*****I*****I
2                                I****I****I
3          I****I****I
4          I****I****I
5            I****I****I
6                                        I****I****I
7                                 I****I****I
        +---------+---------+---------+---------+---------+---------+
      10.50     11.00     11.50     12.00     12.50     13.00     13.50
```

SMALL CLEAR BENDING TEST

COLUMN 1 = SPECIMEN NUMBER
COLUMN 2 = MATERIAL CLASS (1 = LIVE LODGEPOLE, 2 = DEAD PINE LESS THAN 5 YRS., 3 = DEAD PINE 5+ YRS., 4 = PINE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE THINNINGS, 8 = FIR THINNINGS
COLUMN 3 = MOR (PSI)
COLUMN 4 = MOE (PSI)

2BL	3	11015.9	1346285.1
14BL	3	11816.5	1422015.4
21BL	3	10649.6	1341967.8
1BL	3	11075.8	1373137.2
3BL	3	11527.3	1534058.6
18BL	3	11733.4	1519744.7
18BL	3	10538.8	1433518.2
21BL	3	7026.0	1144440.2
14BL	3	11513.3	1461204.8
21BL	3	11253.0	1479421.4
4BL	3	11413.9	1435643.9
0BL	3	9190.0	1202938.6
20BL	3	9214.3	911912.9
15BL	3	10863.1	1351953.4
12BL	3	12195.2	1535507.5
5BL	3	9501.3	1125394.1
7BL	3	12150.6	1381925.2
3BL	3	10822.7	1487113.2
33ST	7	9494.8	1409961.0
21ST	7	9993.3	1423656.1
12ST	7	9642.3	1113069.3
37ST	7	11004.0	1489295.4
14ST	7	12169.7	1612686.0
7ST	8	10463.1	1273404.3
23ST	7	8427.4	1238923.2
28ST	7	9026.6	1282471.5
10ST	7	6581.9	478464.5
8ST	7	11115.0	1664573.4
35ST	7	12899.4	1761261.9
29ST	7	10823.6	1381766.1
6ST	7	10556.3	1107602.6
24ST	7	10544.8	1417679.2
22ST	8	8367.9	1182280.9
31ST	7	10005.4	1197727.2
28ST	8	8799.1	1166648.0
25ST	7	11833.2	1427236.1
15ST	7	10439.2	1549798.1
34ST	7	8269.3	1224276.3
21DS	6	6773.1	1005560.5
1DS	6	8036.0	1161002.5
31DS	6	7841.9	1116722.2
2DS	6	7102.2	972202.7
20DS	6	7133.6	981037.8
5DS	6	7805.4	933052.0
29DS	6	7808.8	1109133.1
27DS	6	7508.6	1014728.5
26DS	6	8734.3	1082642.0
15DS	6	6654.3	697313.4
16DS	6	8241.6	1054963.2

2DS	6	6830.9	761939.6
21DS	6	7078.6	1032806.2
17DS	6	6496.1	855168.1
23DS	6	5880.3	674488.8
30DS	6	7984.2	1034848.3
28DS	6	9186.4	1154341.7
16DS	6	8030.1	1002497.0
6DS	6	7261.4	1042811.1
22DS	6	7642.6	1014685.9
3LS	5	8309.1	1027461.1
12LS	5	8377.4	1223888.6
16LS	5	7322.1	1105807.7
12LS	5	7652.8	1080400.0
14LS	5	9252.4	1390350.3
5LS	5	7967.7	1069294.2
5LS	5	7075.2	1079155.2
16LS	5	8078.1	1220700.4
19LS	5	7818.7	1194738.8
4LS	5	8581.9	1301984.1
6LS	5	8644.3	1219046.5
20LS	5	4378.7	941184.6
17LS	5	8855.9	1183407.7
8LS	5	8883.7	1217926.2
20LS	5	7068.4	997701.0
16LS	5	7751.4	1064797.0
7LS	5	7967.5	1209369.2
16LS	5	8005.2	1148604.3
7LS	5	7782.9	975668.1
16LS	5	8792.3	1160981.4
4LL	1	10207.2	1075335.1
22LL	1	10252.7	1349436.2
37LL	1	9276.1	1264082.1
32LL	1	9927.3	1436121.8
28LL	1	12814.6	1723715.2
2LL	1	12118.9	1608692.0
1LL	1	11033.9	1566711.2
23LL	1	12368.7	1732065.0
12LL	1	10765.8	1402404.6
26LL	1	10052.3	1390243.9
29LL	1	13299.9	1856143.1
35LL	1	10252.6	1472768.6
31LL	1	11510.7	1634499.9
33LL	1	8571.3	1123849.3
23LT	4	10310.2	1416901.6
24LT	4	12570.4	2162225.1
29LT	4	11862.5	1962330.6
16LT	4	10327.3	1767185.0
24LT	4	13012.8	1933925.9
21LT	4	14520.0	2403661.0
9LT	4	11577.6	2160791.8
12LT	4	15756.9	2715080.8
16LT	4	14248.1	2411918.9
5LT	4	11150.1	1923902.0
11LT	4	10489.7	1391359.0
17LT	4	12944.6	1964920.0
4LT	4	14728.7	2356147.7
14LT	4	13243.3	2233474.6
28LT	4	11321.0	1846792.8
25LT	4	10847.6	1796191.3
29LT	4	11863.0	2022722.1
32LT	4	13669.9	1984097.5
11LT	4	10406.7	1733569.0
4LT	4	14787.8	2288866.9
19AL	2	10778.3	1522175.6
11AL	2	12447.5	1439094.1
6AL	2	10123.0	1382462.6
9AL	2	10981.6	1412259.7
13AL	2	12049.0	1745945.4
23AL	2	11466.2	2069358.0
5AL	2	9900.6	1970185.2
22AL	2	10704.4	1932607.5
20AL	2	10608.7	1323997.4
1AL	2	11955.7	2065582.2
18AL	2	12460.1	1935648.3
15AL	2	10871.6	1610414.8
13AL	2	10497.9	1612188.1
3AL	2	8212.9	949190.8
14AL	2	11415.2	1404047.3
16AL	2	10905.5	1664611.3

APPENDIX B

SMALL CLEAR BENDING TEST

TEST FOR NORMALITY

HISTOGRAMS

And

NORMAL SCORES VERSUS DATA PLOTS

HIST FOR MOE FOR LIVE PINE C41

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
1100000.	2	**
1200000.	0	
1300000.	2	**
1400000.	3	***
1500000.	1	*
1600000.	3	***
1700000.	2	**
1800000.	0	
1900000.	1	*

--

? HIST FOR MOE FOR DEAD PINE (5 YRS. <) C42

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
900000.	1	*
1000000.	0	
1100000.	0	
1200000.	0	
1300000.	1	*
1400000.	4	****
1500000.	1	*
1600000.	2	**
1700000.	2	**
1800000.	0	
1900000.	2	**
2000000.	1	*
2100000.	2	**

--

? HIST FOR MOE FOR DEAD PINE (5+ YRS) C43

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
900000.	1	*
1000000.	0	
1100000.	2	**
1200000.	1	*
1300000.	2	**
1400000.	6	******
1500000.	6	******

--

? HIST MOE FOR PINE THINNINGS C44

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
1400000.	2	**
1600000.	0	
1800000.	4	****
2000000.	6	******
2200000.	4	****
2400000.	3	***
2600000.	0	
2800000.	1	*

--

```
? HIST MOE FOR LIVE SPRUCE C45

    MIDDLE OF     NUMBER OF
    INTERVAL      OBSERVATIONS
    950000.          1       *
   1000000.          2       **
   1050000.          3       ***
   1100000.          3       ***
   1150000.          2       **
   1200000.          7       *******
   1250000.          0
   1300000.          1       *
   1350000.          0
   1400000.          1       *
```

--

```
? HIST MOE FOR DEAD SPRUCE C46

    MIDDLE OF     NUMBER OF
    INTERVAL      OBSERVATIONS
    650000.          1       *
    700000.          1       *
    750000.          1       *
    800000.          0
    850000.          1       *
    900000.          0
    950000.          2       **
   1000000.          5       *****
   1050000.          4       ****
   1100000.          3       ***
   1150000.          2       **
```

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```
? HIST MOE FOR SPRUCE-FIR THINNINGS C47

    MIDDLE OF     NUMBER OF
    INTERVAL      OBSERVATIONS
    400000.          1       *
    600000.          0
    800000.          0
   1000000.          0
   1200000.          9       *********
   1400000.          6       ******
   1600000.          3       ***
   1800000.          1       *
```

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 HIST MOR FOR LIVE PINE C21

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
     8500.         1     *
     9000.         0
     9500.         1     *
    10000.         3     ***
    10500.         2     **
    11000.         2     **
    11500.         1     *
    12000.         1     *
    12500.         1     *
    13000.         1     *
    13500.         1     *

--
? HIST MOR FOR DEAD PINE (5 YRS. <) C22

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
     8000.         1     *
     8500.         0
     9000.         0
     9500.         0
    10000.         2     **
    10500.         3     ***
    11000.         4     ****
    11500.         2     **
    12000.         2     **
    12500.         2     **

--
? HIST MOR FOR DEAD PINE (5+ YRS.) C23

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
     7000.         1     *
     7500.         0
     8000.         0
     8500.         0
     9000.         2     **
     9500.         1     *
    10000.         0
    10500.         2     **
    11000.         4     ****
    11500.         5     *****
    12000.         3     ***

--
? HIST MOR FOR PINE THINNINGS C24

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
    10500.         4     ****
    11000.         2     **
    11500.         2     **
    12000.         2     **
    12500.         1     *
    13000.         3     ***
    13500.         1     *
    14000.         1     *
    14500.         2     **
    15000.         1     *
    15500.         0
   [illegible]     1     *
```

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--
? HIST MOR FOR LIVE SPRUCE C25

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
      4500.        1      *
      5000.        0
      5500.        0
      6000.        0
      6500.        0
      7000.        2      **
      7500.        2      **
      8000.        7      *******
      8500.        4      ****
      9000.        3      ***
      9500.        1      *

--
? HIST MOR FOR DEAD SPRUCE C26

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
      6000.        1      *
      6500.        2      **
      7000.        5      *****
      7500.        3      ***
      8000.        7      *******
      8500.        1      *
      9000.        1      *

--
? HIST MOR FOR SPRUCE-FIR THINNINGS C27

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
      7000.        1      *
      8000.        3      ***
      9000.        3      ***
     10000.        5      *****
     11000.        5      *****
     12000.        2      **
     13000.        1      *

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?
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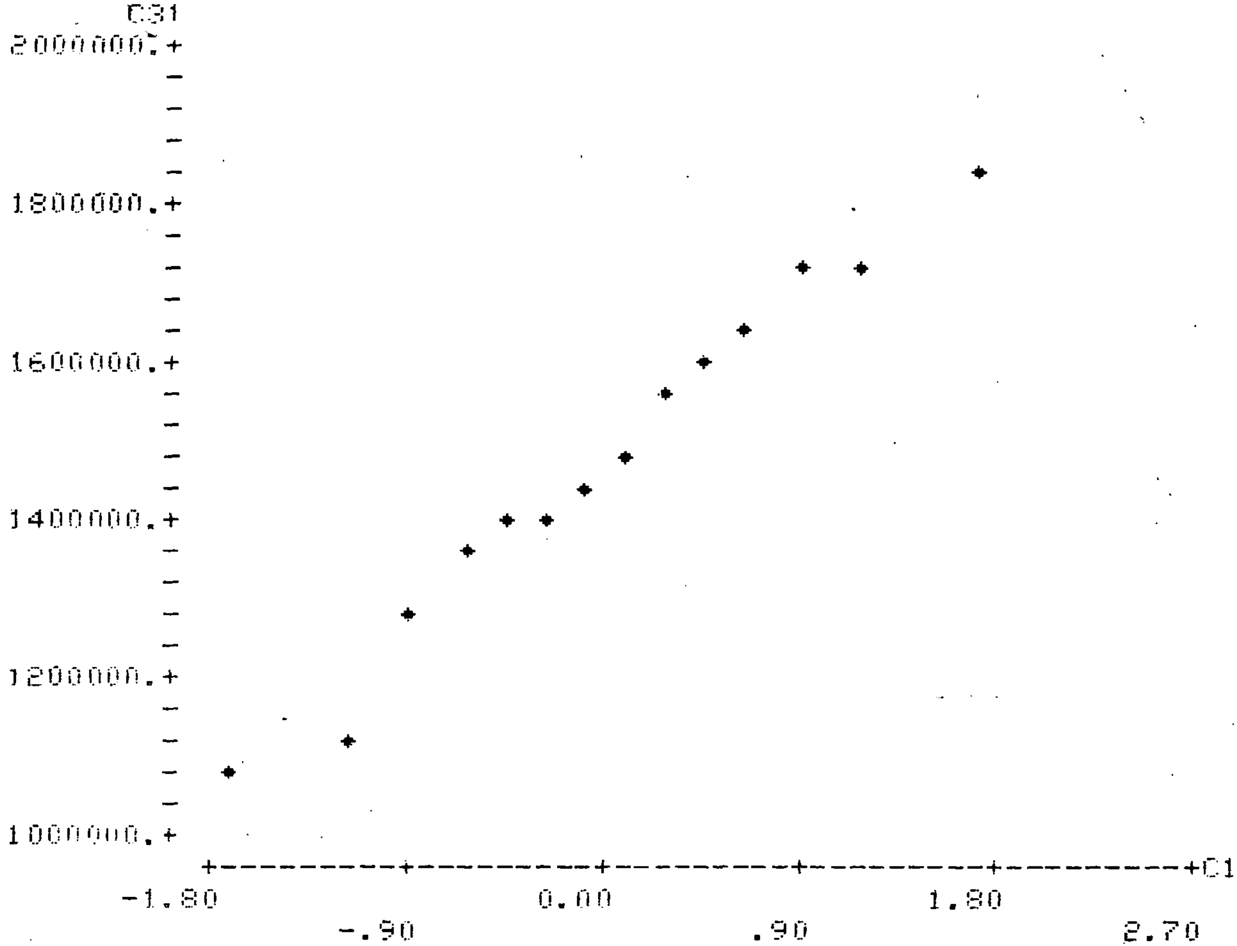
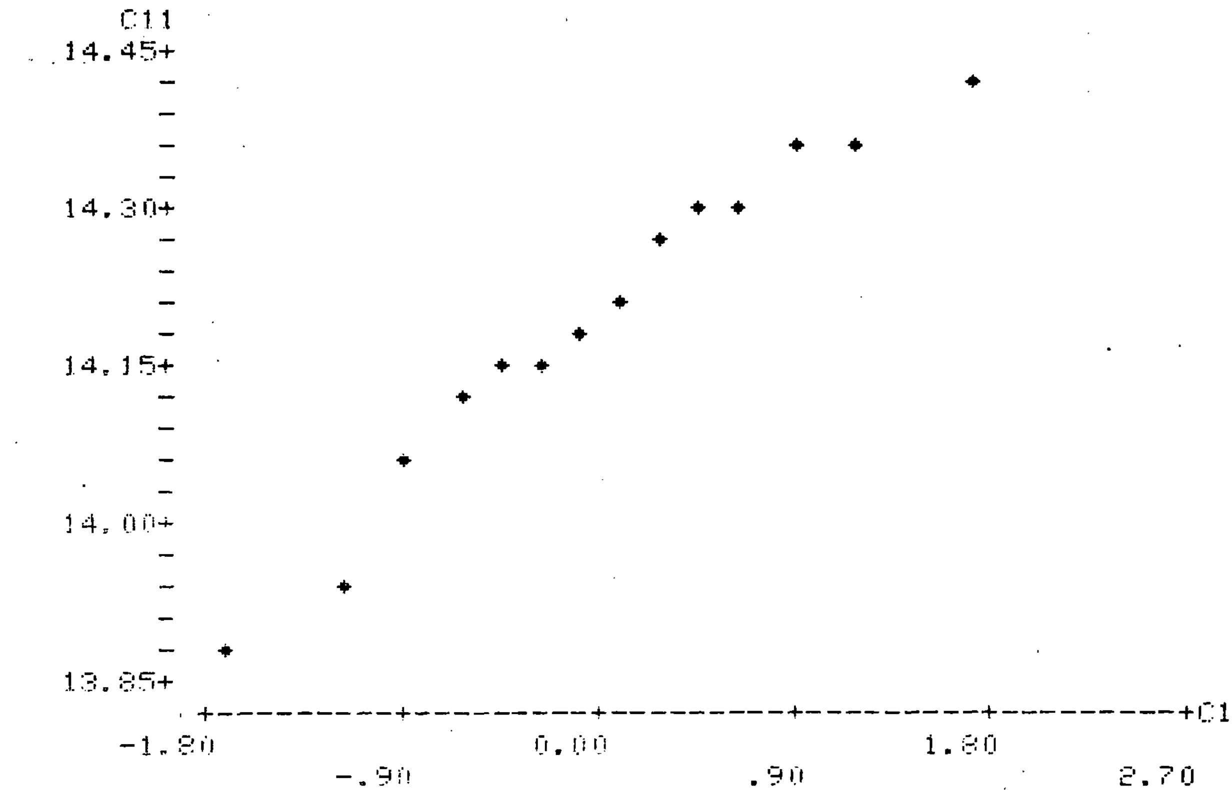
MSCO MOE LIVE PINE C31 C1

PLOT C31 C1



SCO NATURAL LOG MOE LIVE PINE C11 C1

LOT C11 C1



? NSCD MOE DEAD PINE (5 YRS.) C32 C1

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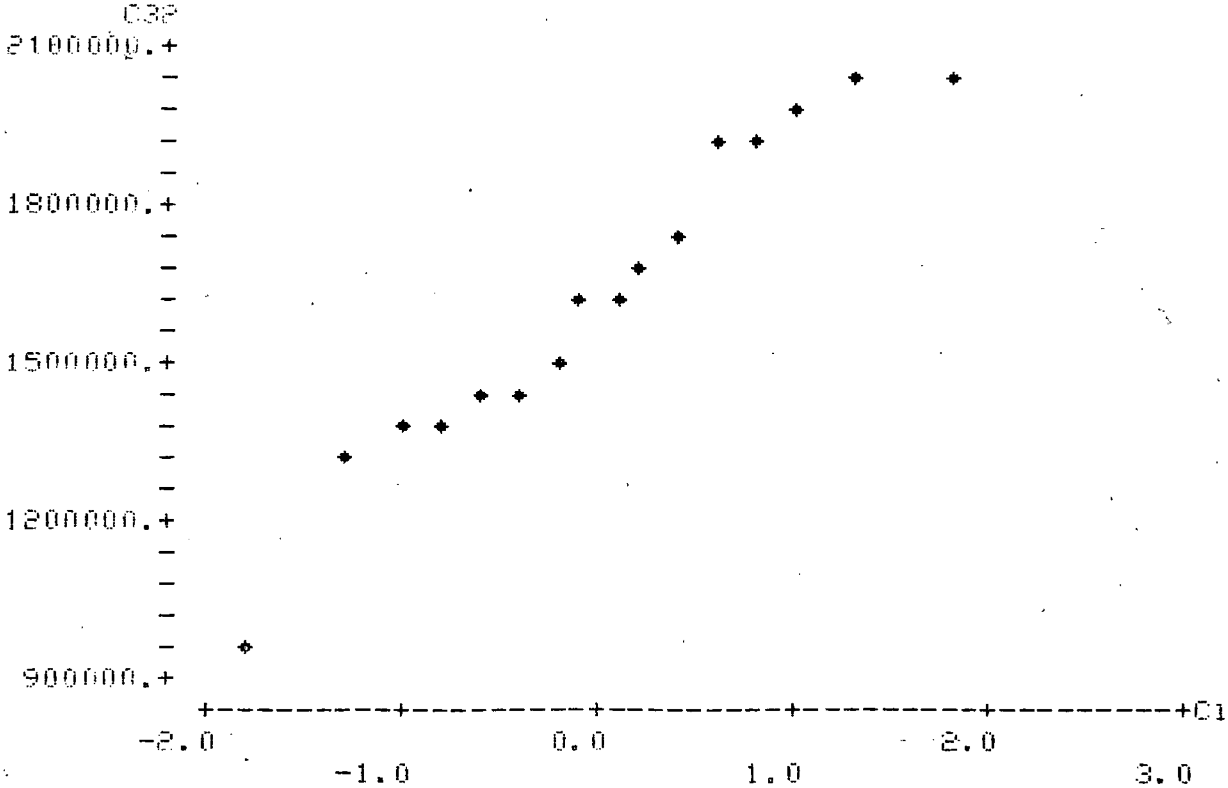
? PLOT C32 C1



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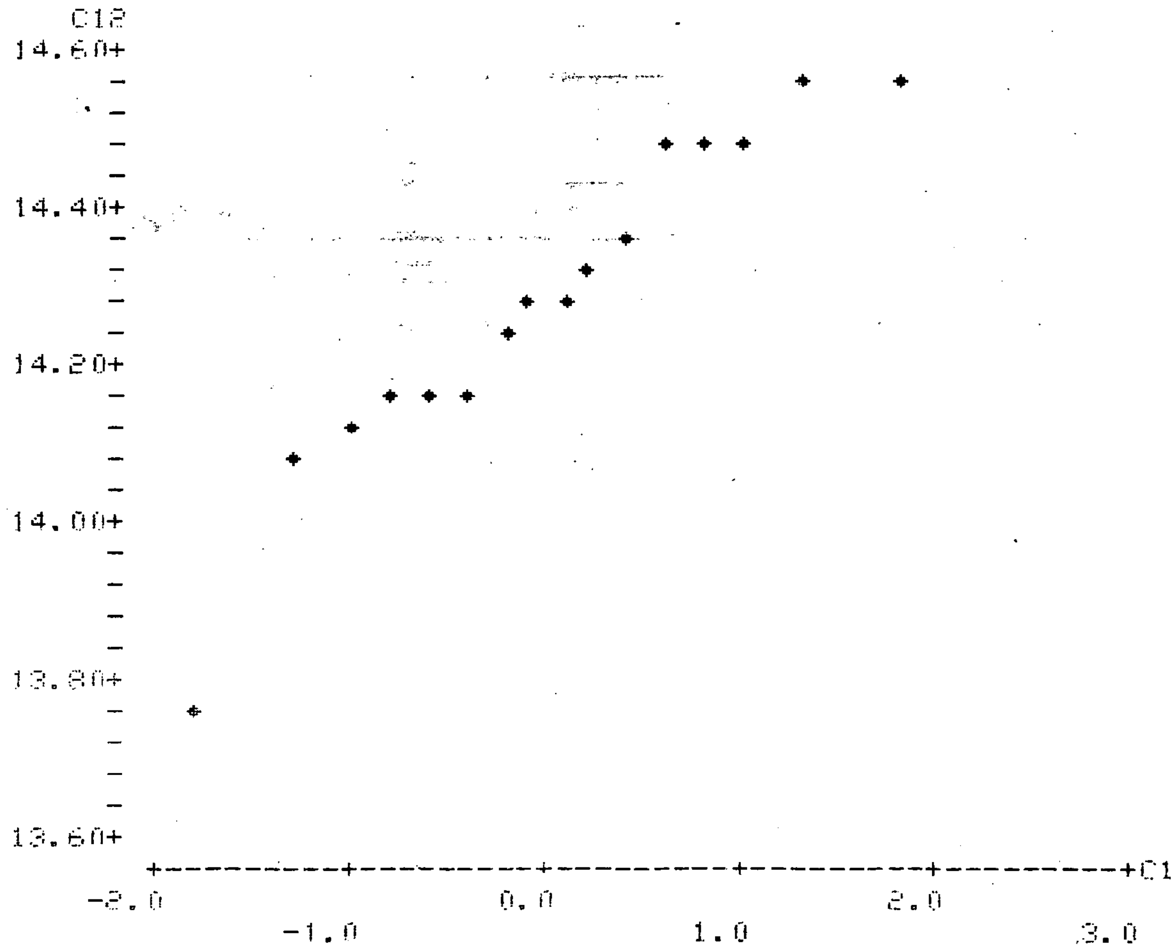
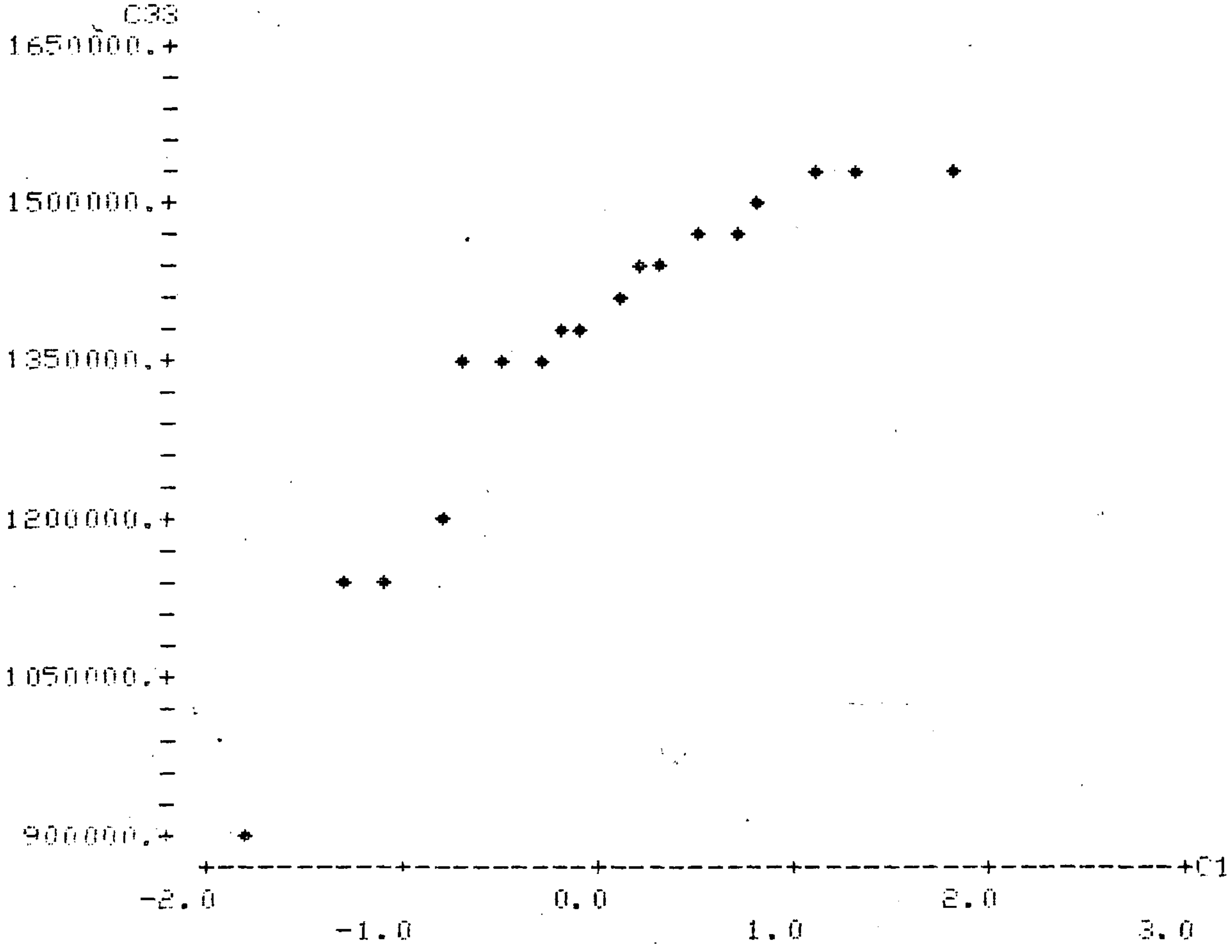
? NSCD NATURAL LOG MOE DEAD PINE (5 YRS.) C12 C1

--

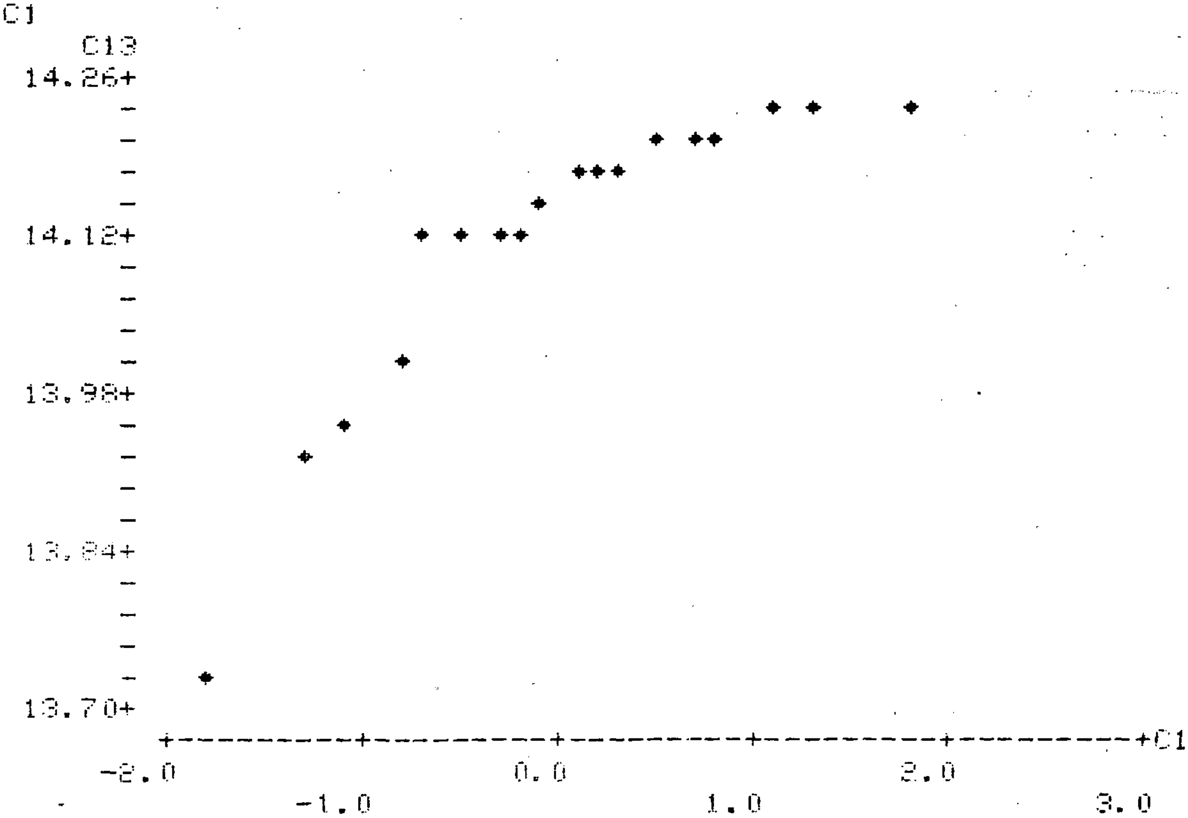
? PLOT C12 C1



--
? NSCO MOE DEAD PINE (5+ YRS.) C33 C1
--
? PLOT C33 C1

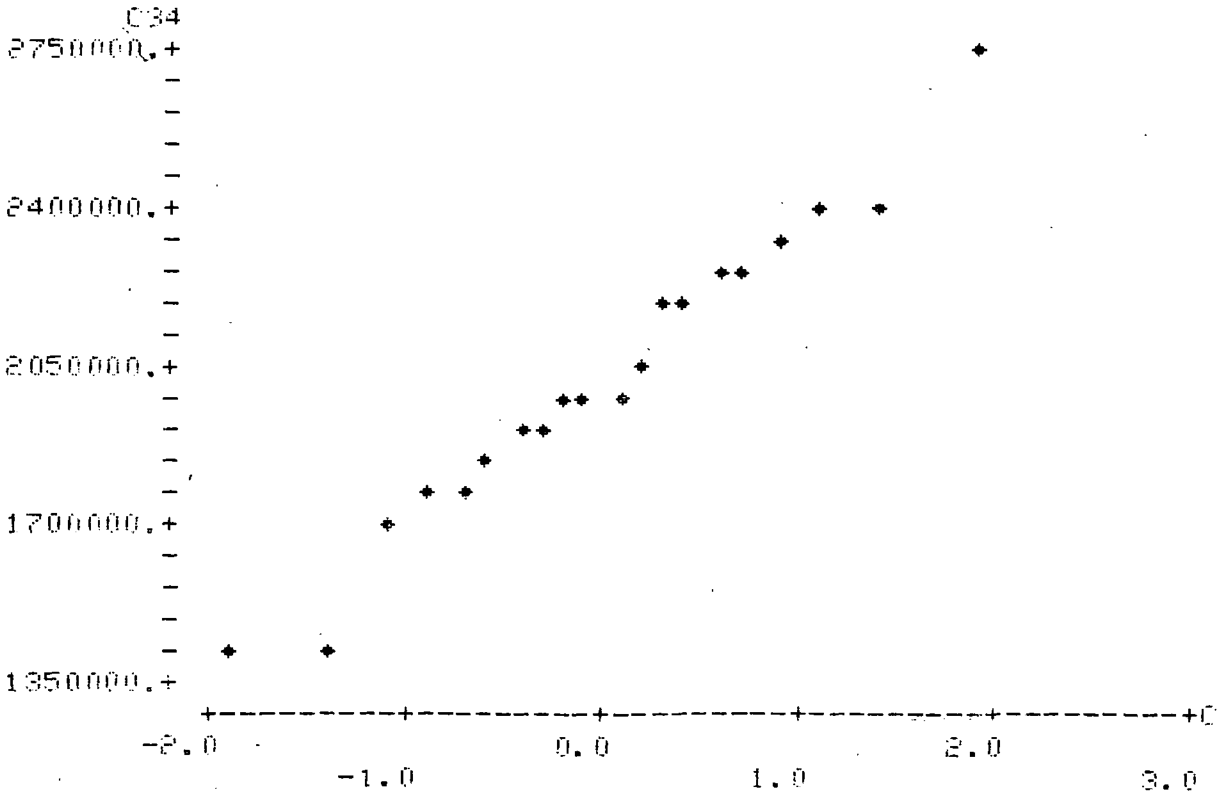


--
? NSCO NATURAL LOG DEAD PINE (5+ YRS.) C13 C1
--
? PLOT C13 C1



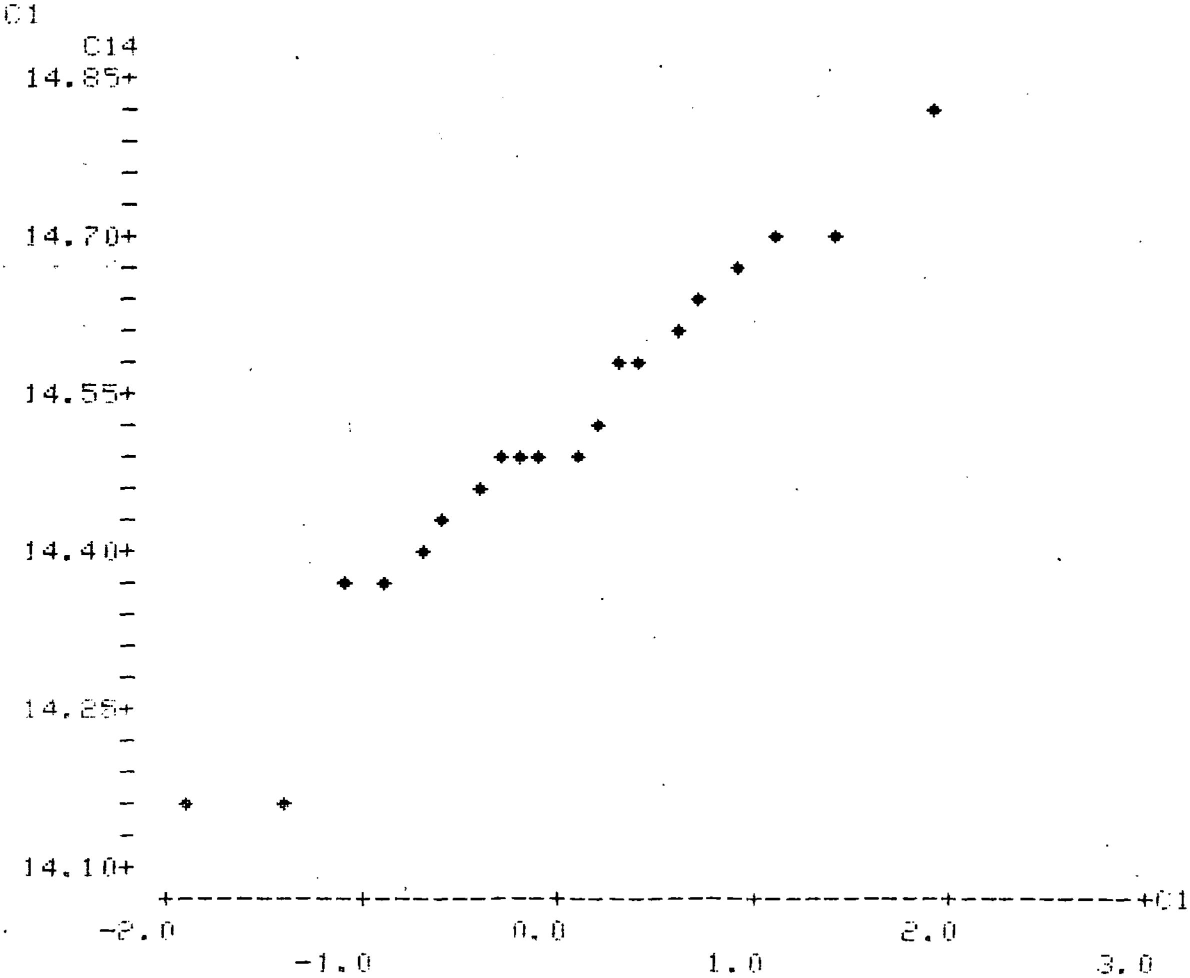
SCD MOE PINE THINNINGS C34 C1

PLOT C34 C1



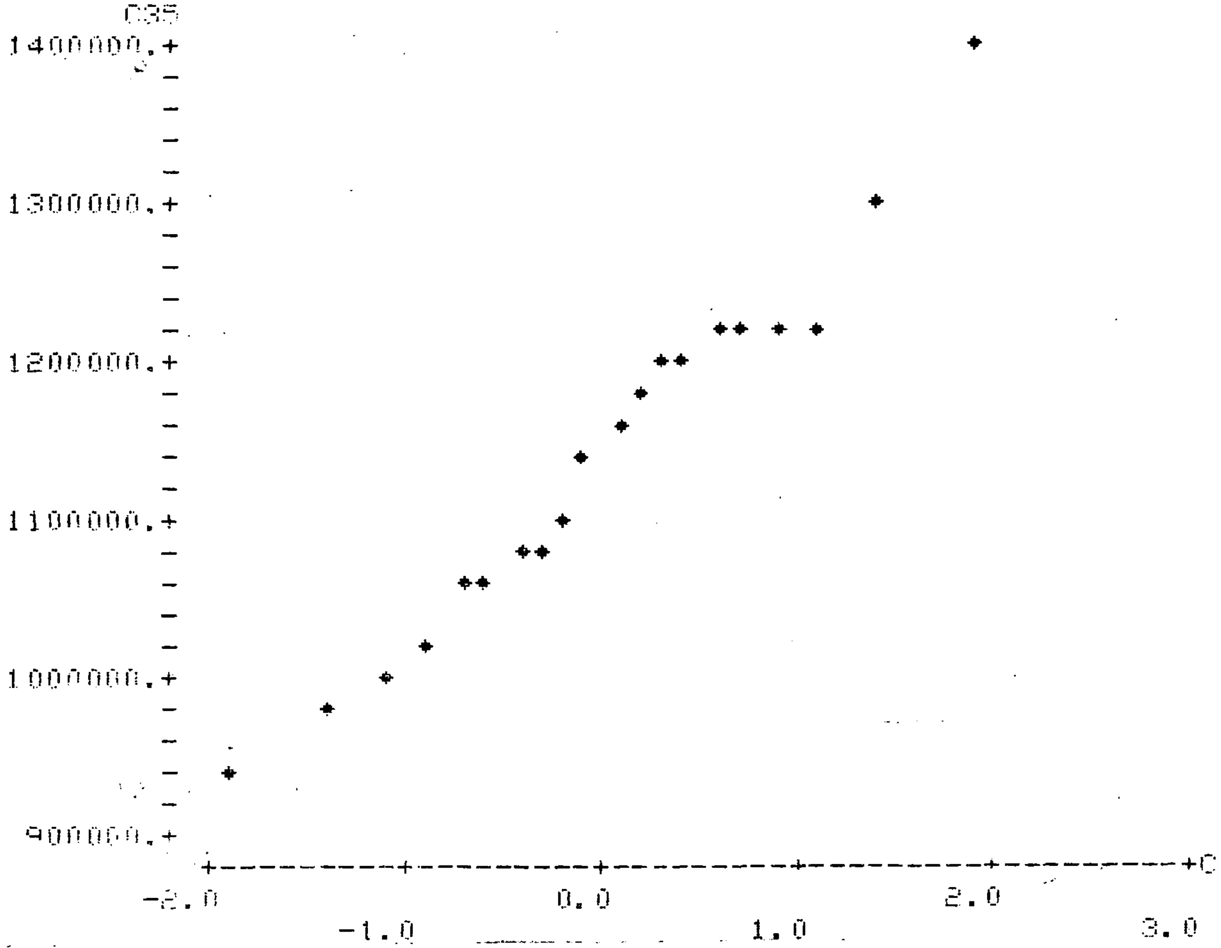
SCD NATURAL LOG MOE PINE THINNINGS C14 C1

PLOT C14 C1



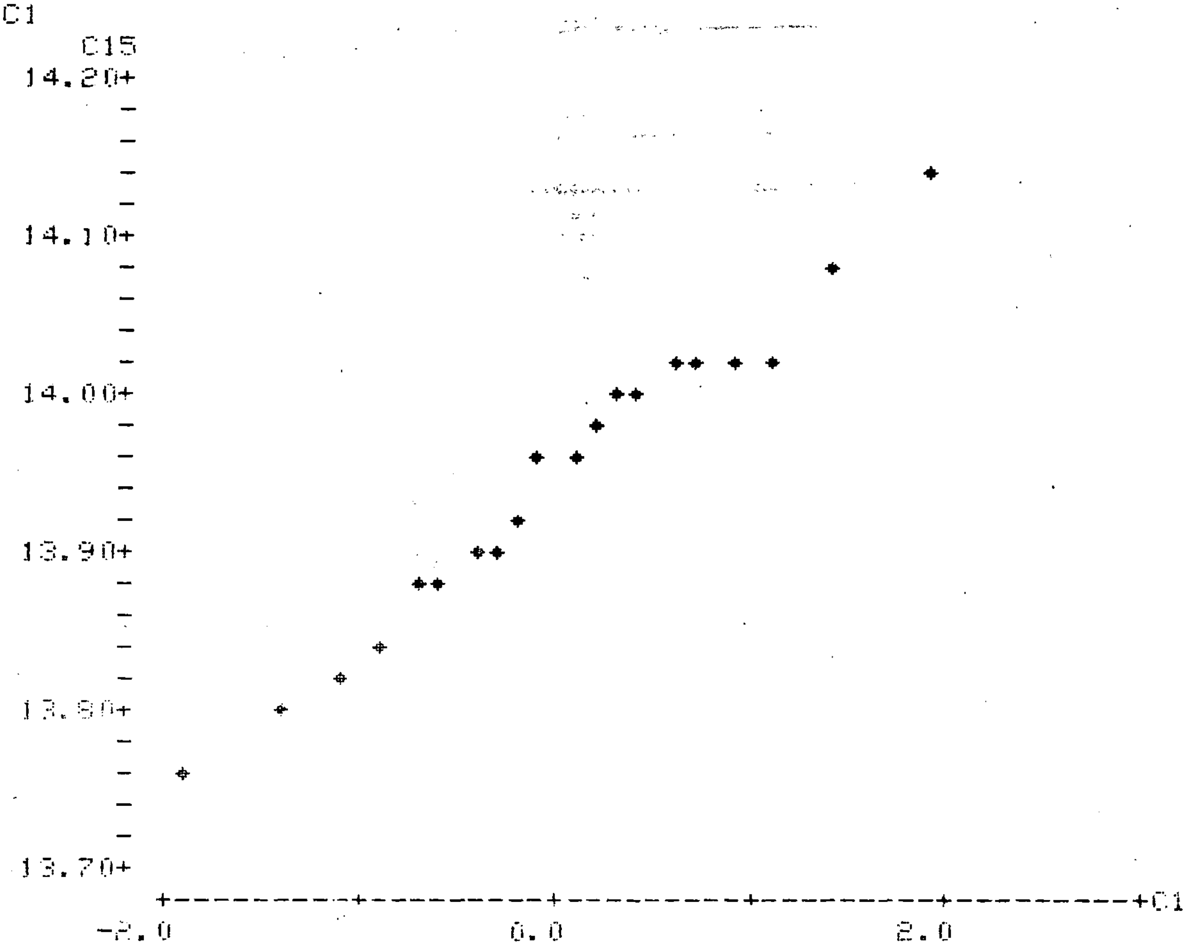
NSCO MOE LIVE SPRUCE C35 C1

PLOT C35 C1



NSCO NATURAL LOG MOE LIVE SPRUCE C15 C1

PLOT C15 C1



NSCD MOE DEAD SPRUCE C36 C1

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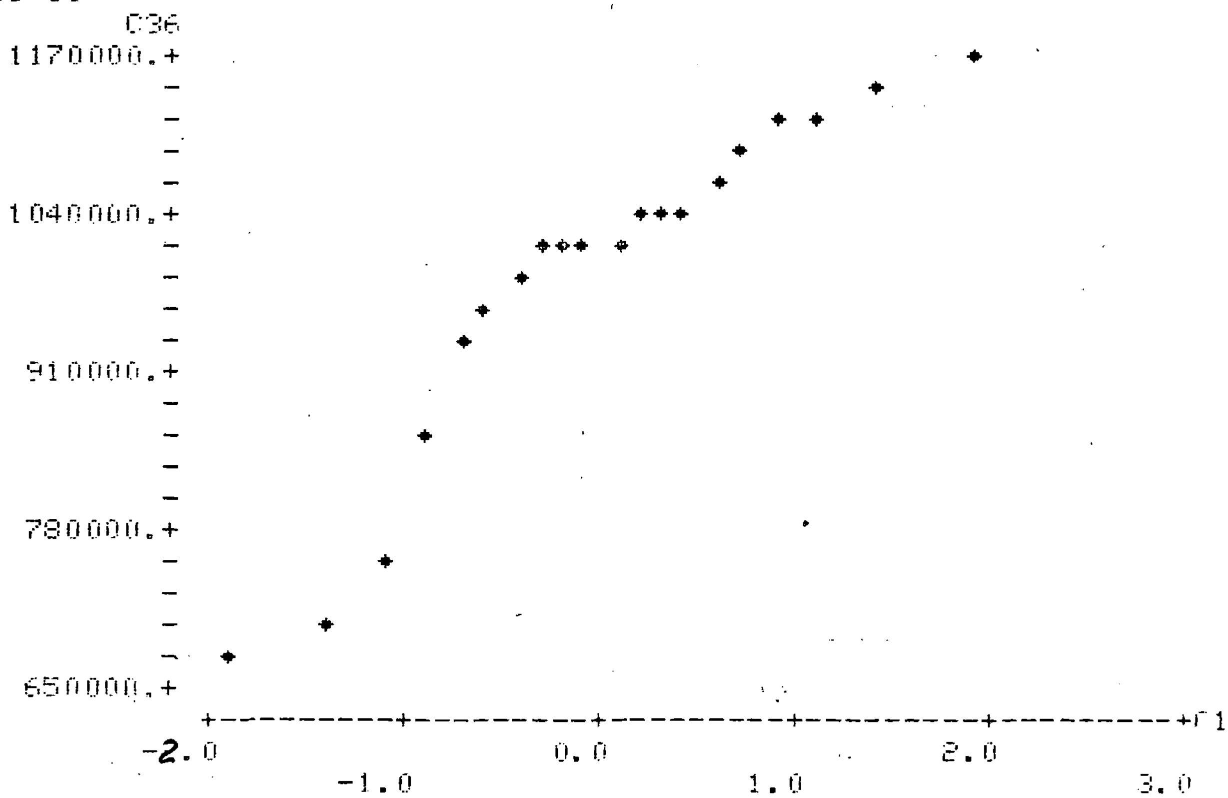
? PLOT C36 C1



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? NSCD NATURAL LOG MOE DEAD SPRUCE C16 C1

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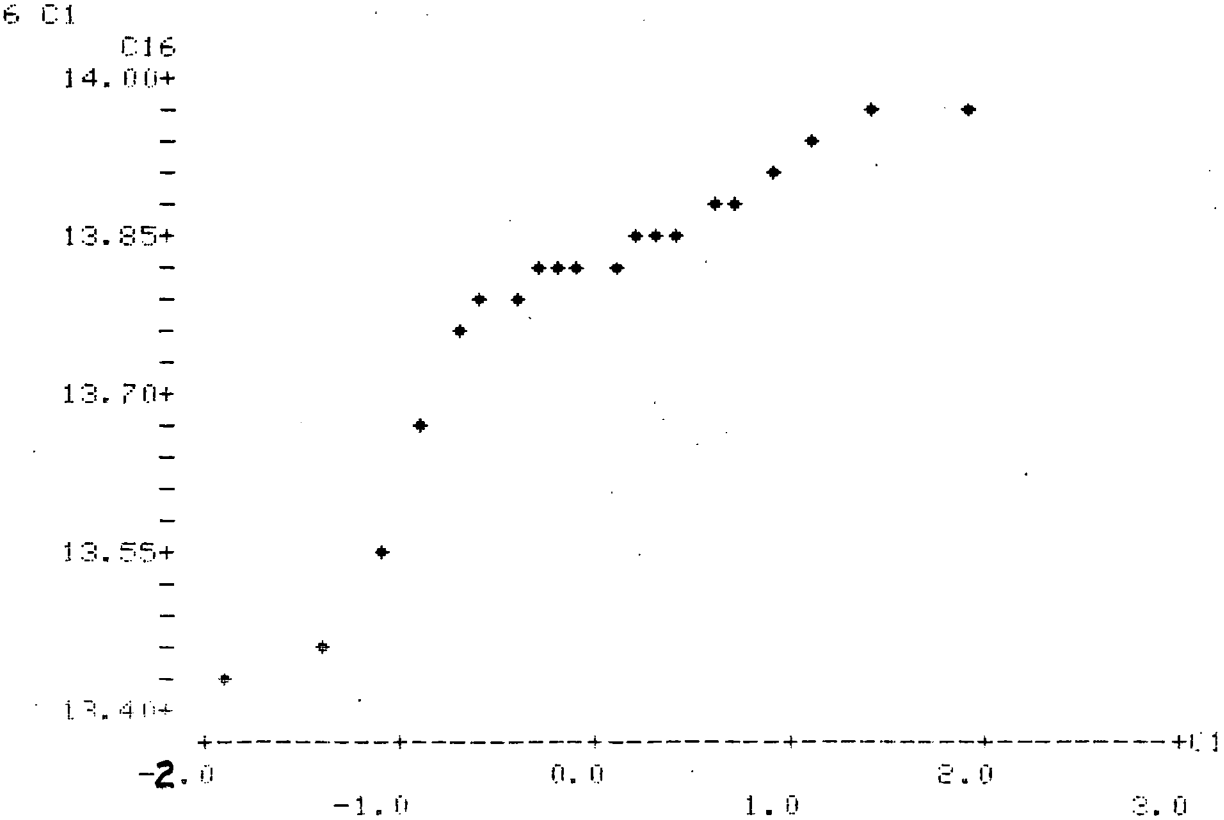
? PLOT C16 C1



MNSCO MOE SPRUCE-FIR THINNINGS C37 C1

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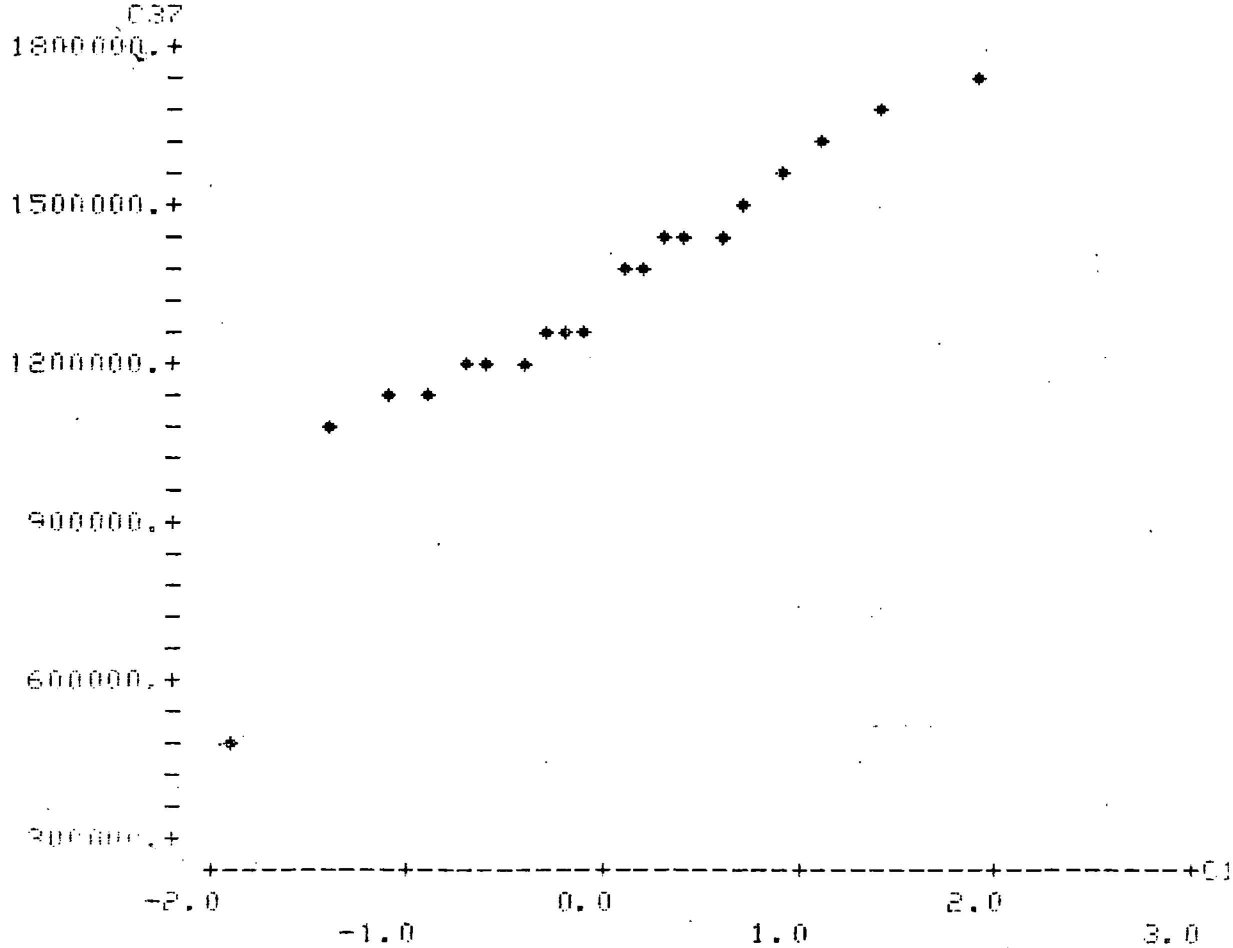
PLOT C37 C1



MNSCO NATURAL LOG MOE SPRUCE-FIR THINNINGS C37 C1

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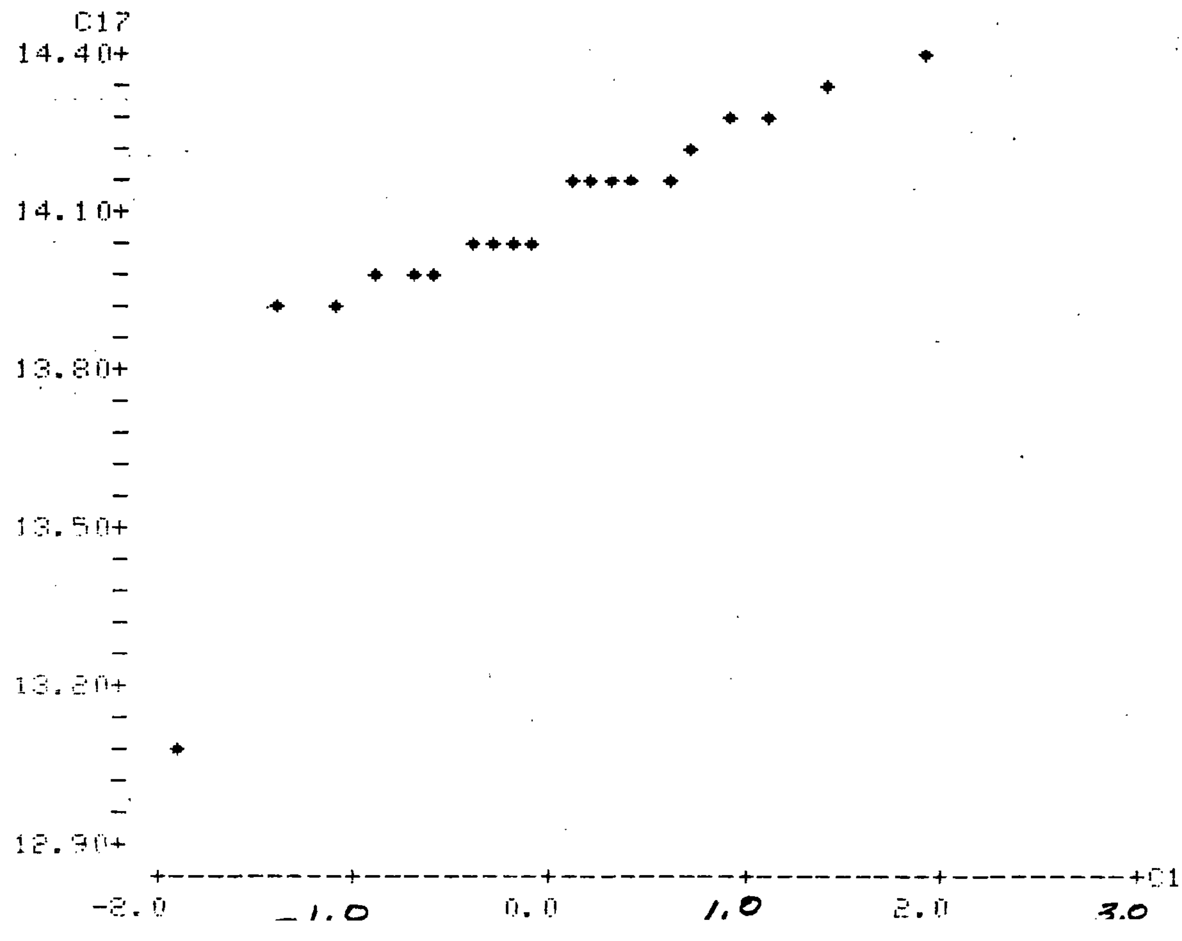
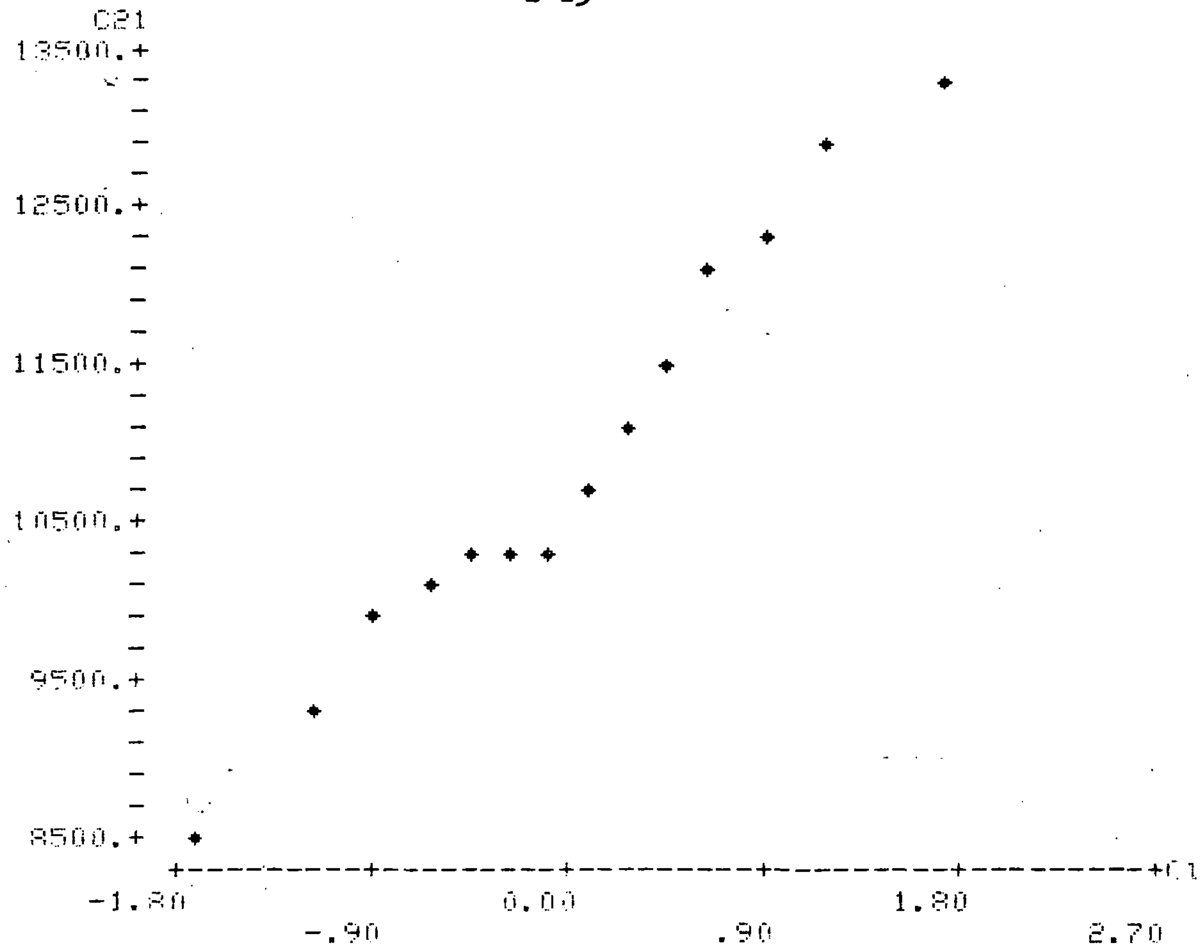
PLOT C17 C1

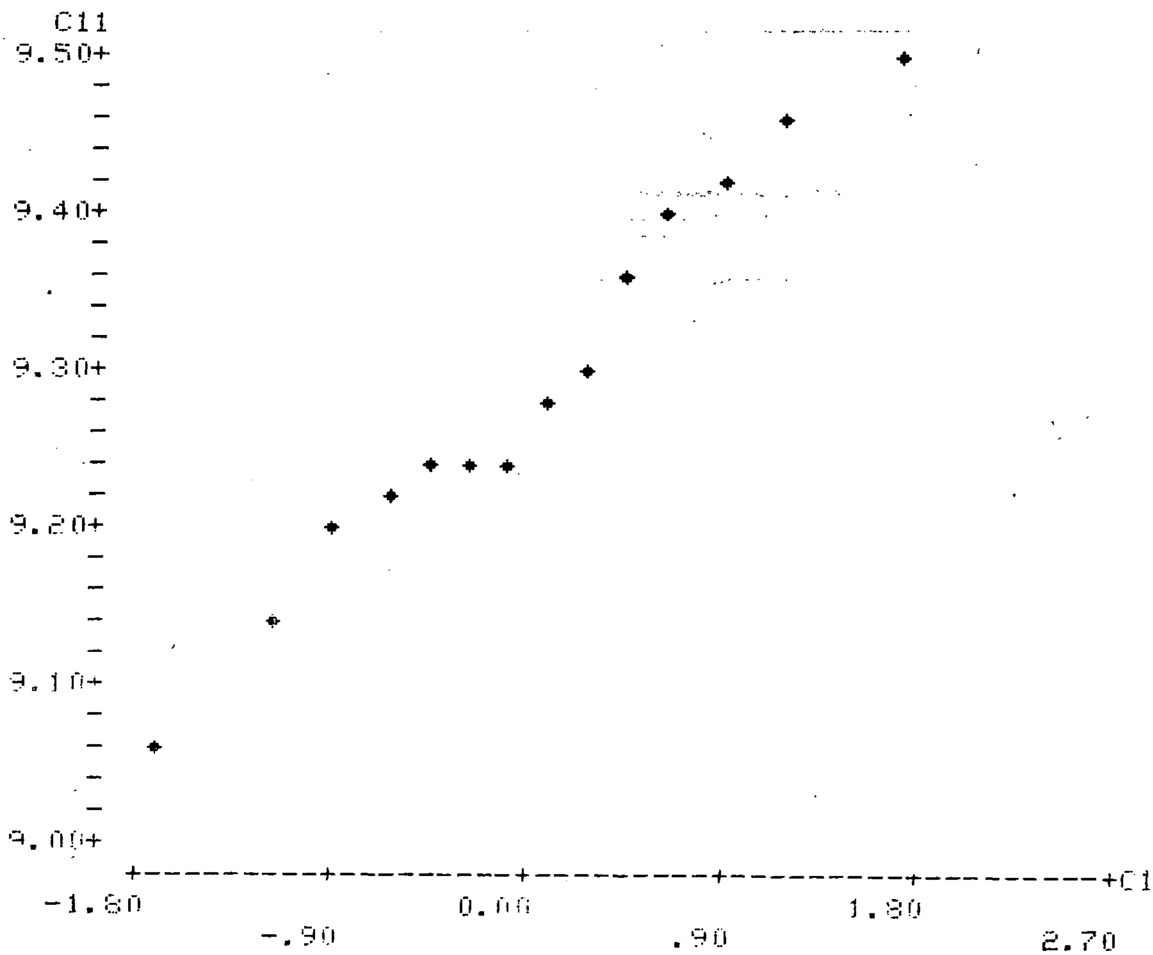


? PLOT C21 C1



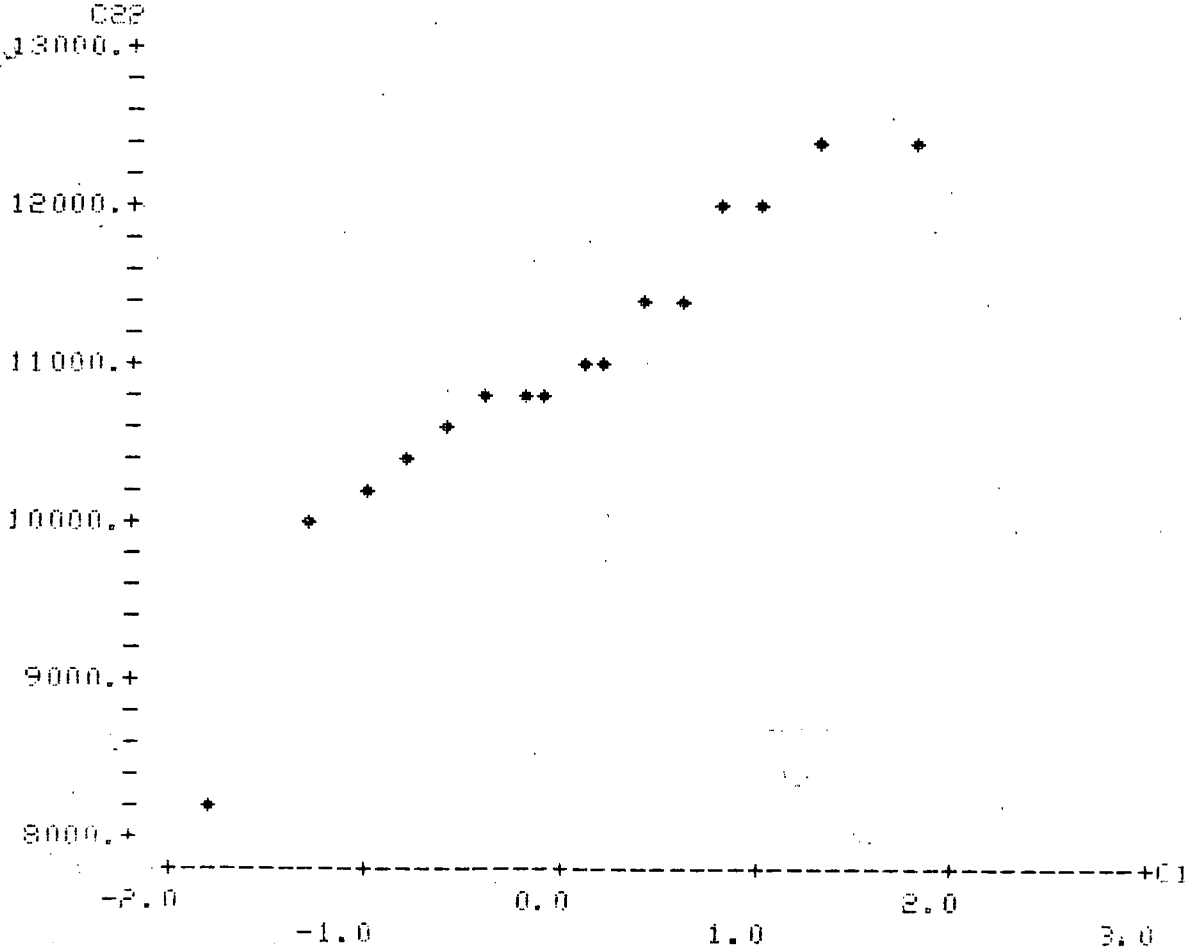
? NSCO NATURAL LOG MOR FOR LIVE PINE C11 C1

? PLOT C11 C1



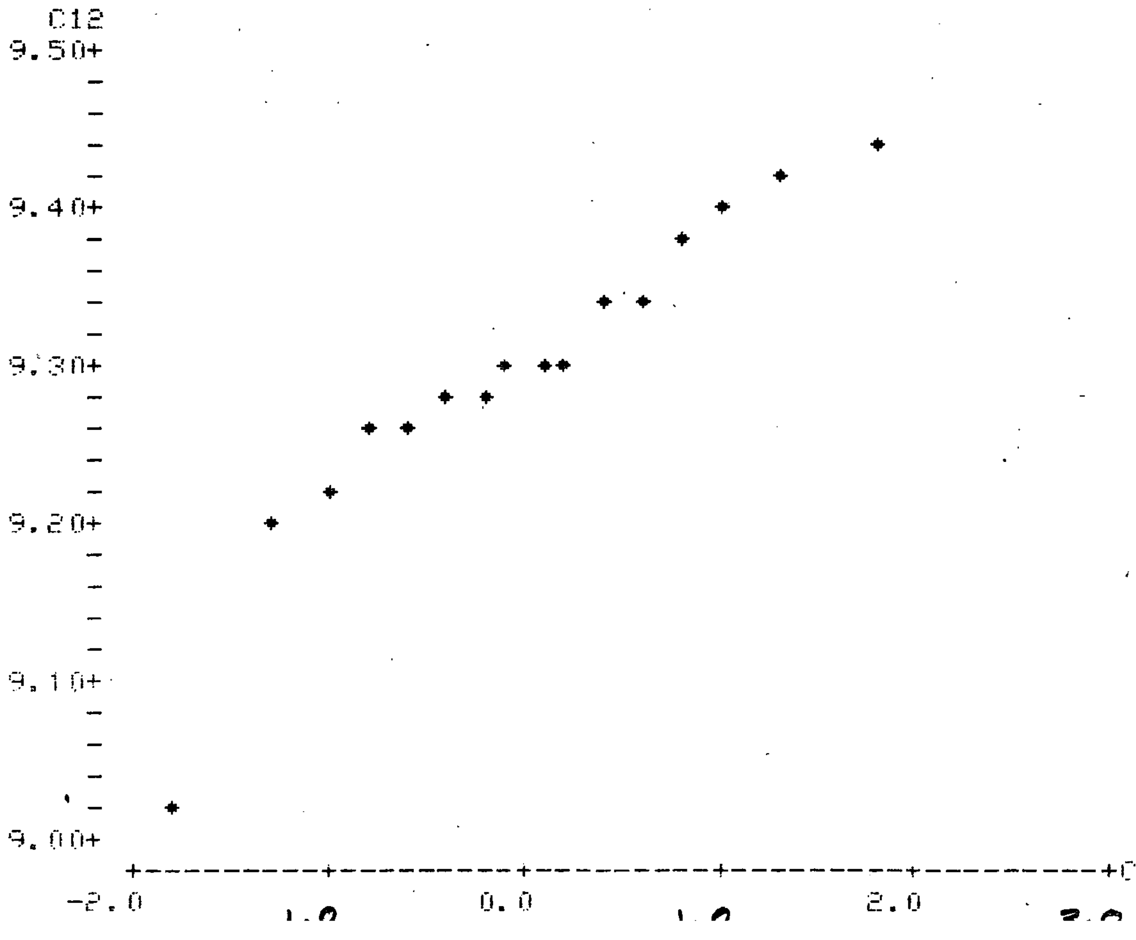
NSCD MOR DEAD PINE (5 YRS.<) C22 C1

? PLOT C22 C1



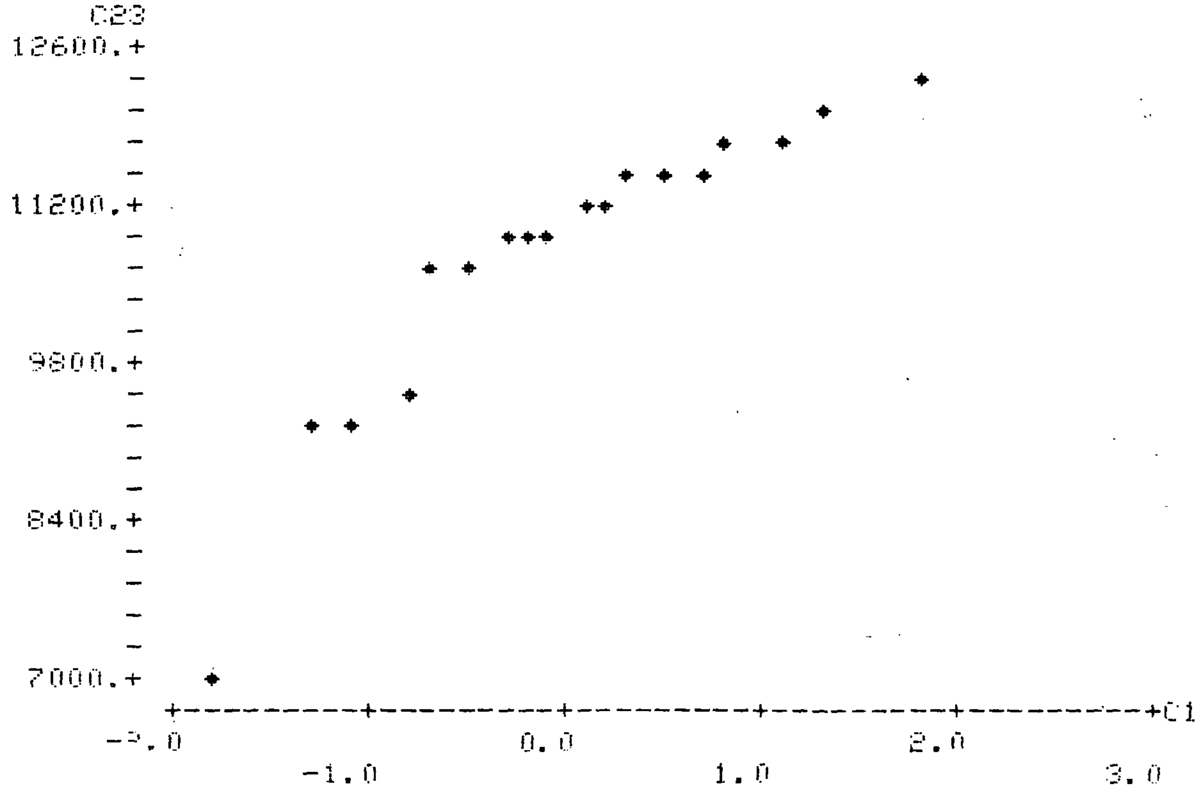
NSCD NATURAL LOG MOR DEAD PINE (5 YRS. <) C12 C1

? PLOT C12 C1



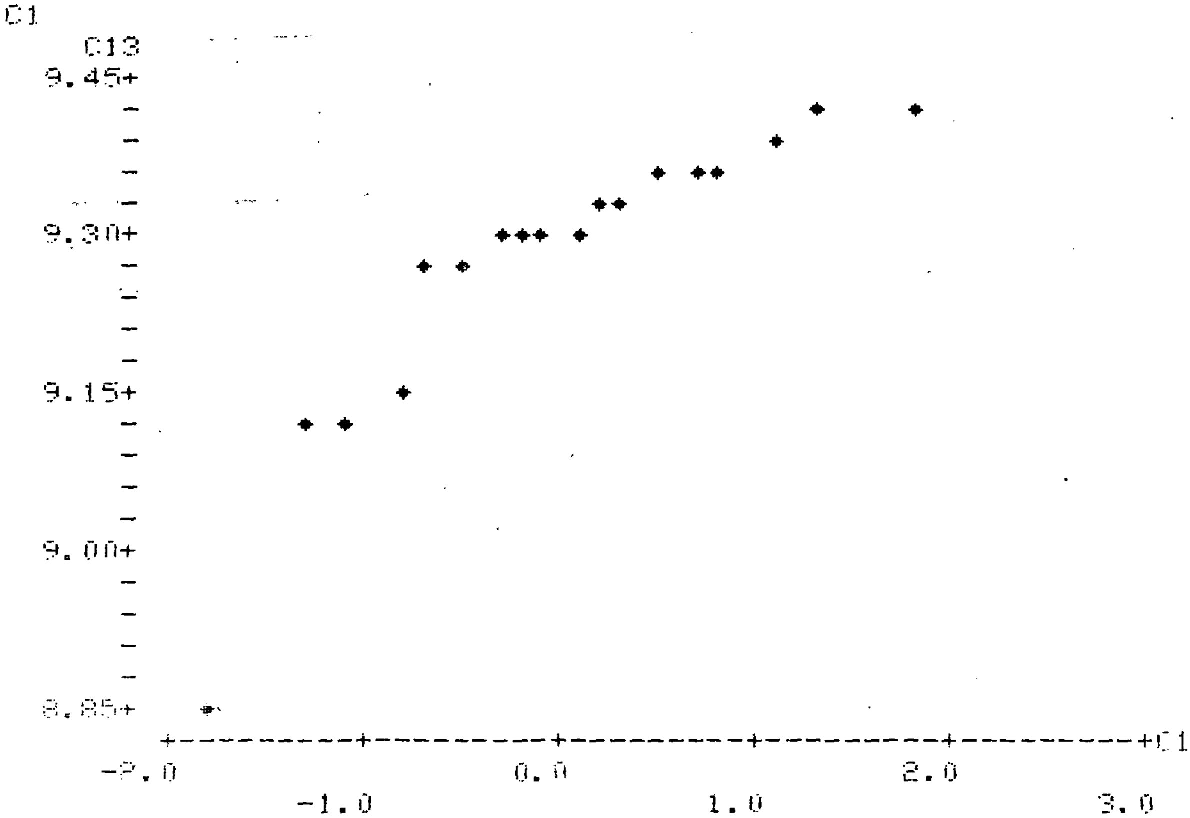
NSCO MOR DEAD PINE (5+ YRS.) C23 C1

PLOT C23 C1



NSCO NATURAL LOG MOR DEAD PINE (5+ YRS.) C13 C1

PLOT C13 C1



H.SCO MOR PINE THINNINGS C24 C1

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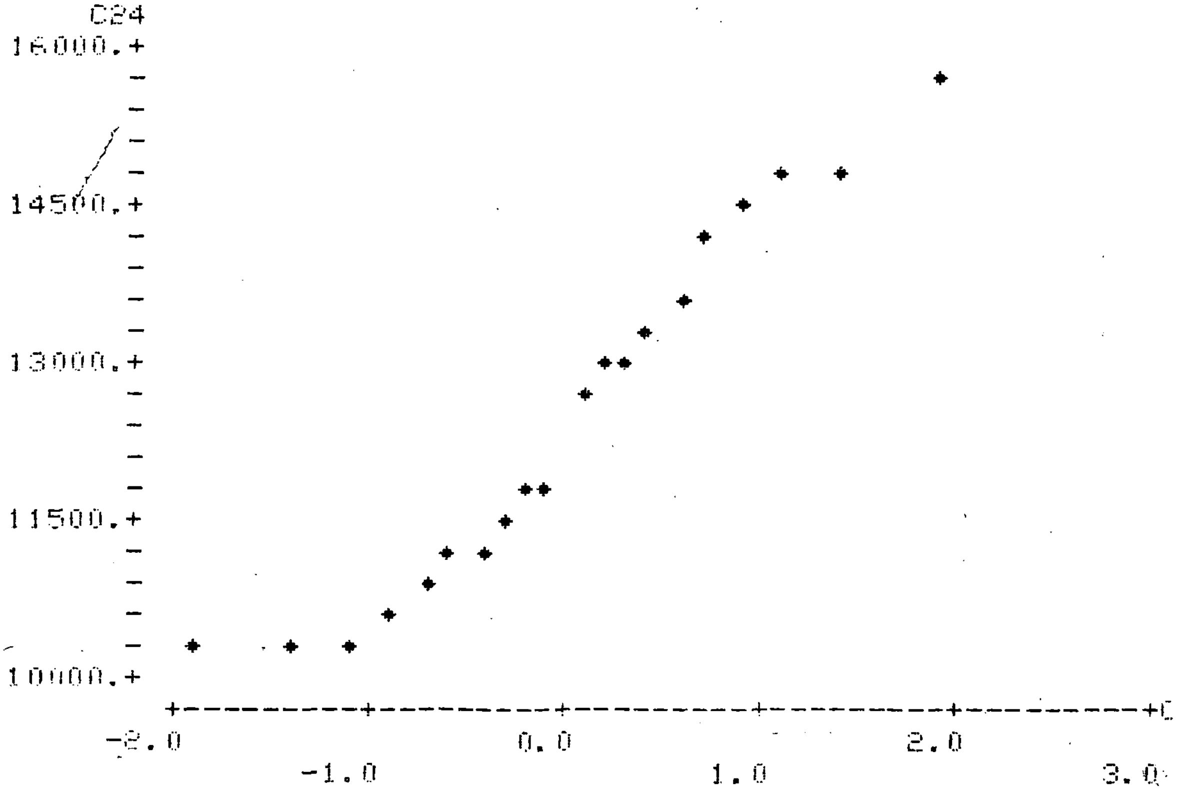
? PLOT C24 C1



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? NSCO NATURAL LOG MOR PINE THINNINGS C14 C1

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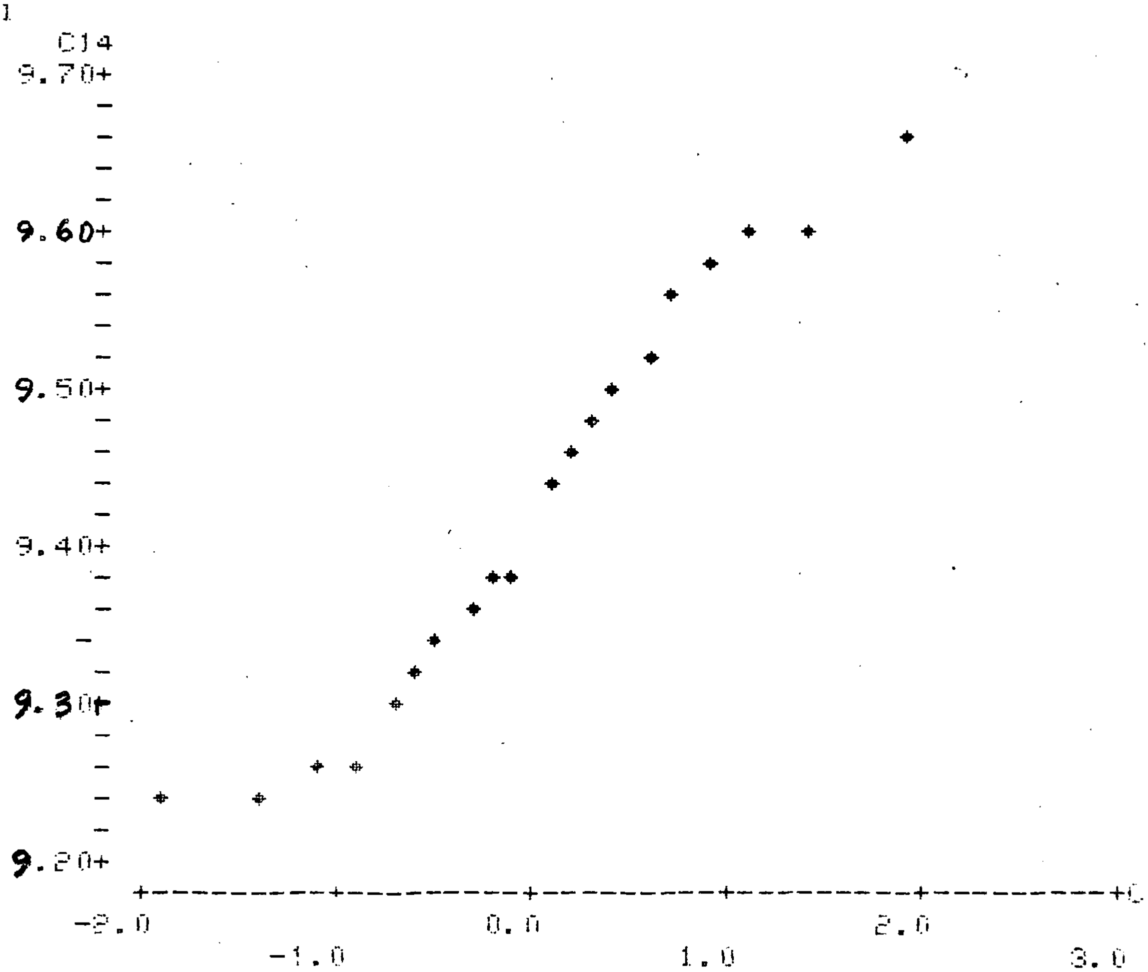
? PLOT C14 C1



NSCD MOR LIVE SPRUCE C25 C1

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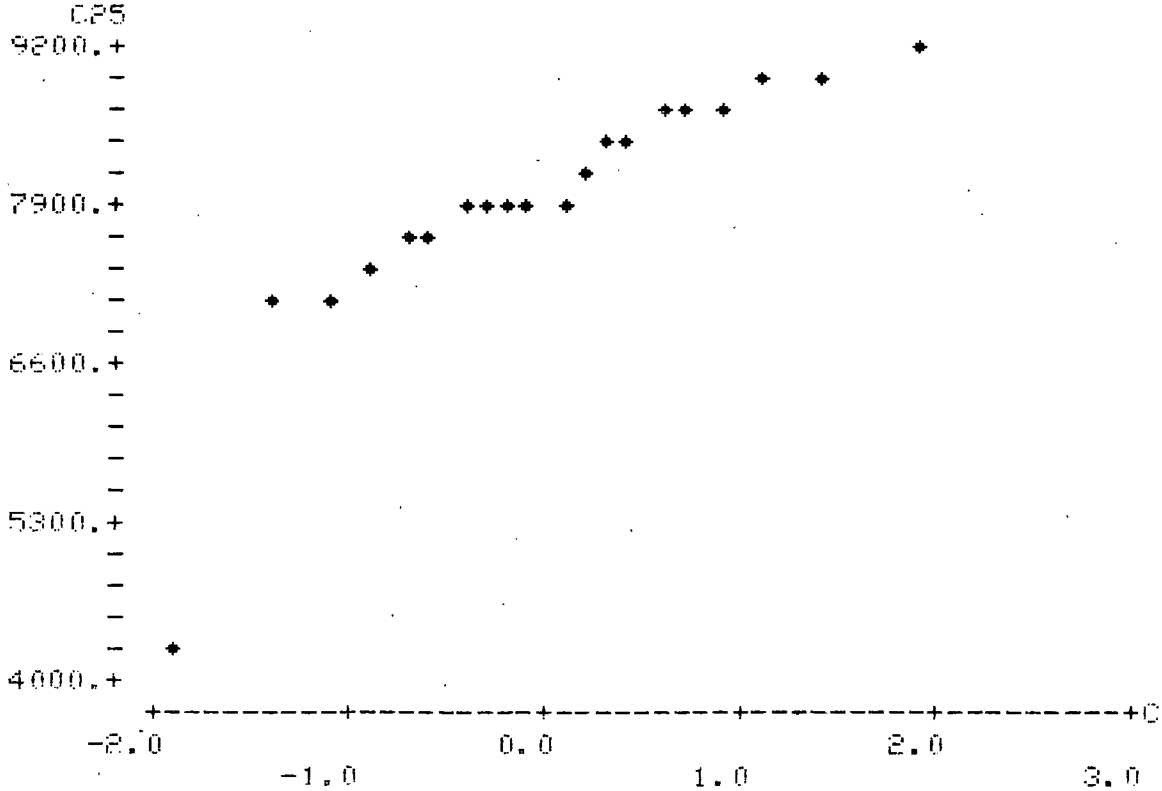
PLOT C25 C1



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NSCD NATURAL LOG MOR LIVE SPRUCE C15 C1

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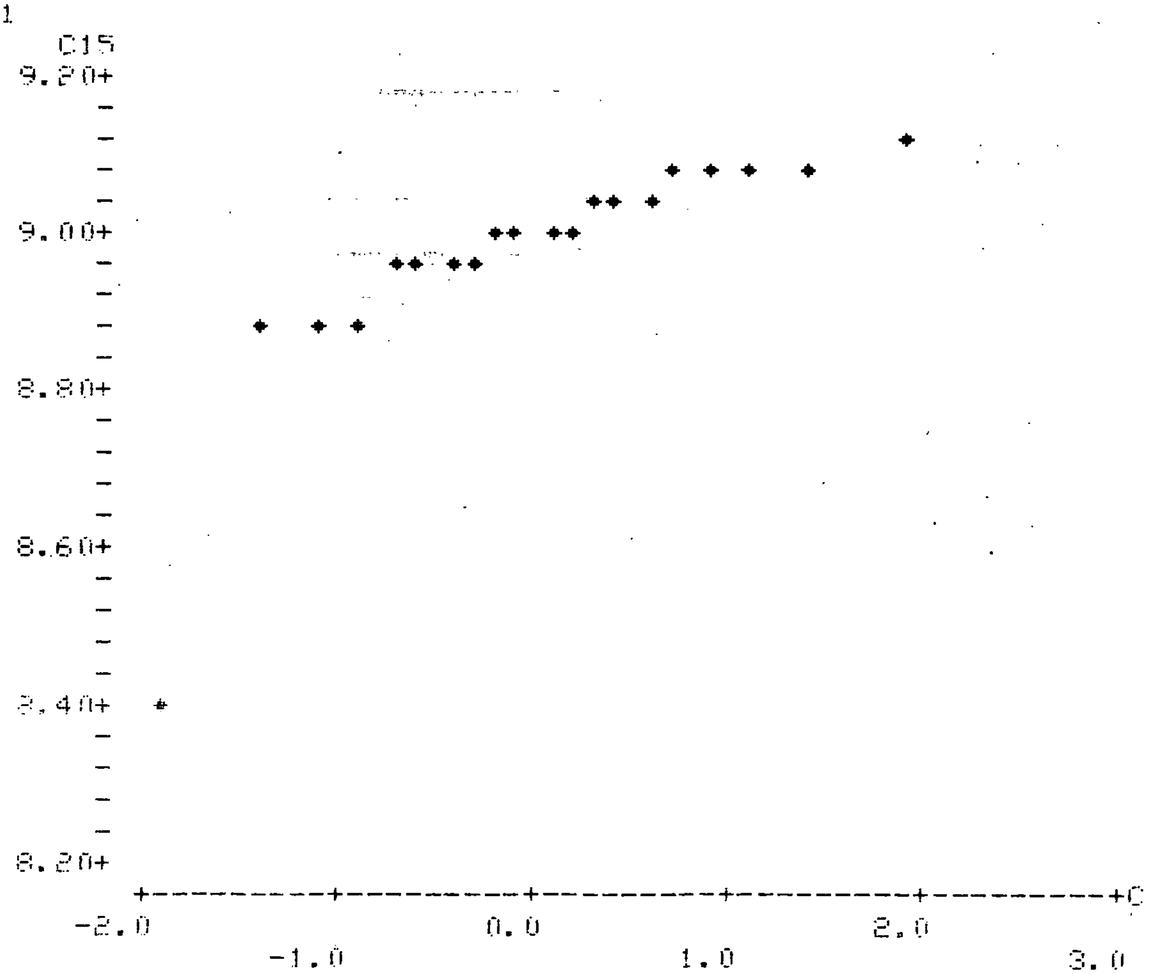
PLOT C15 C1



NSCD MOR DEAD SPRUCE C26 C1

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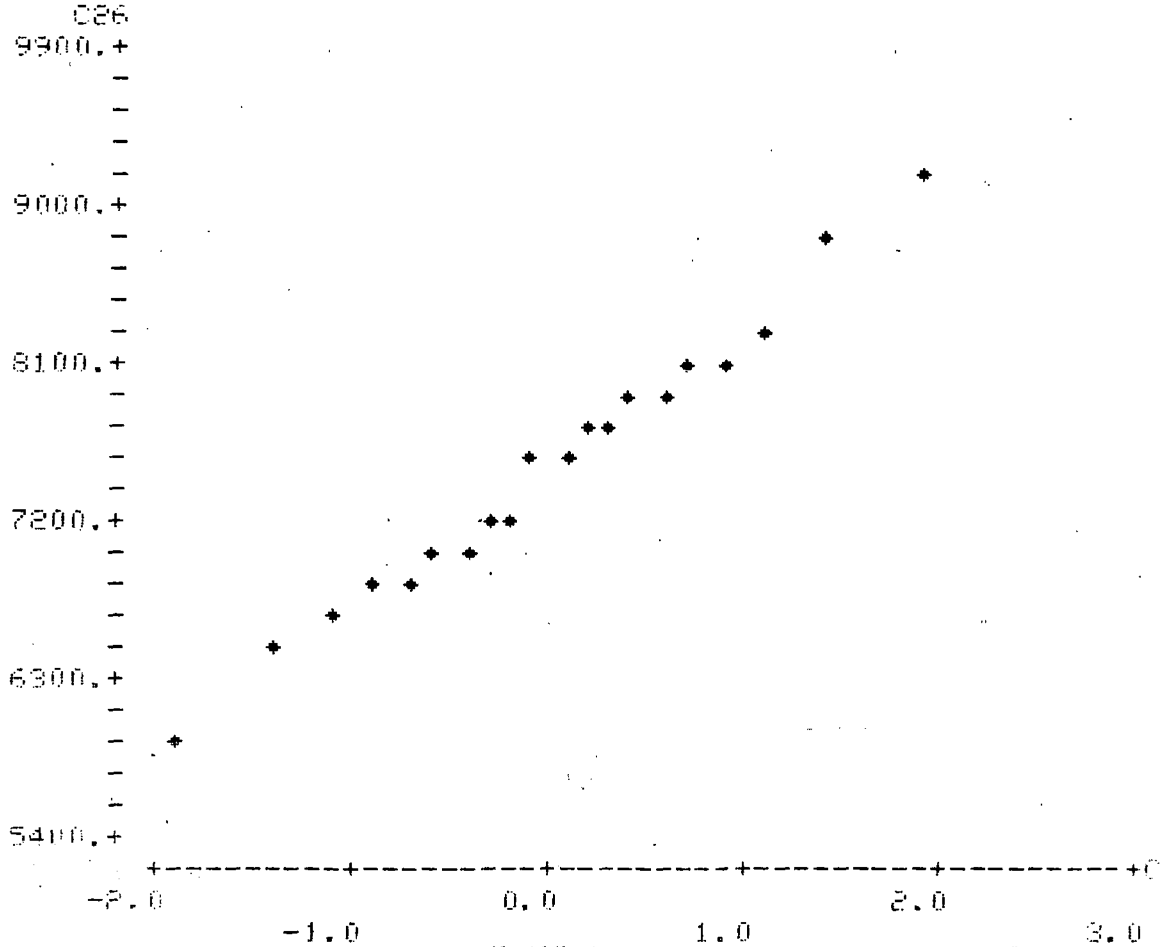
PLOT C26 C1



NSCD NATURAL LOG MOR DEAD SPRUCE C16 C1

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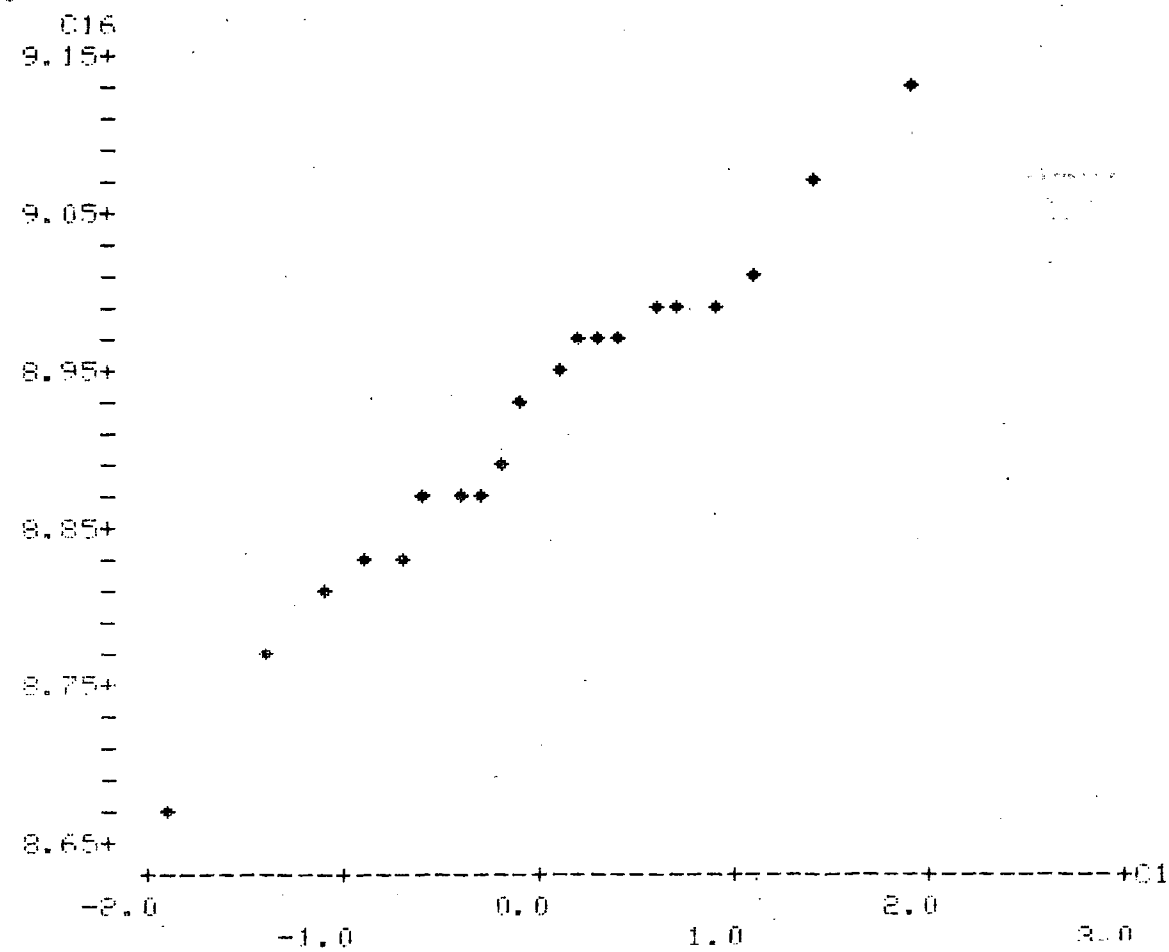
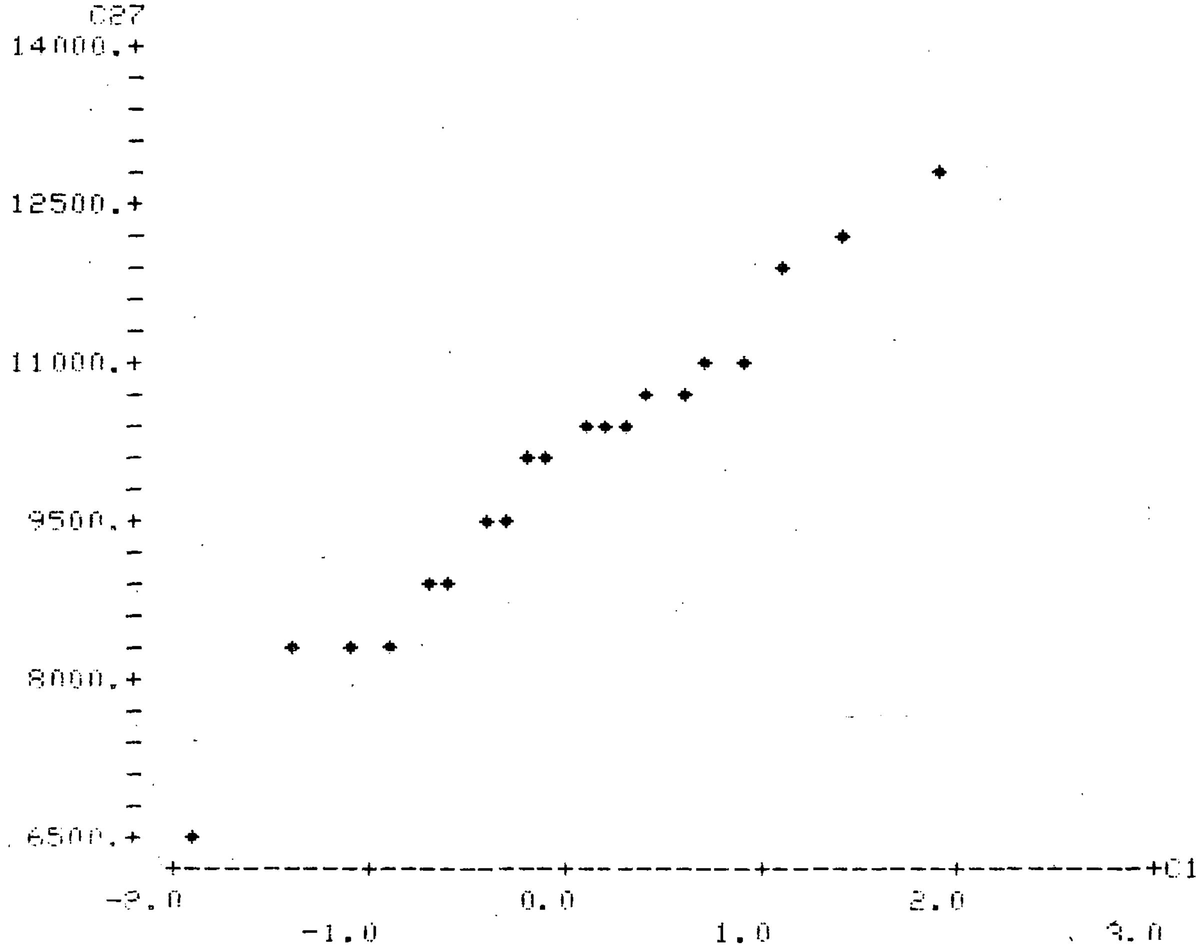
PLOT C16 C1



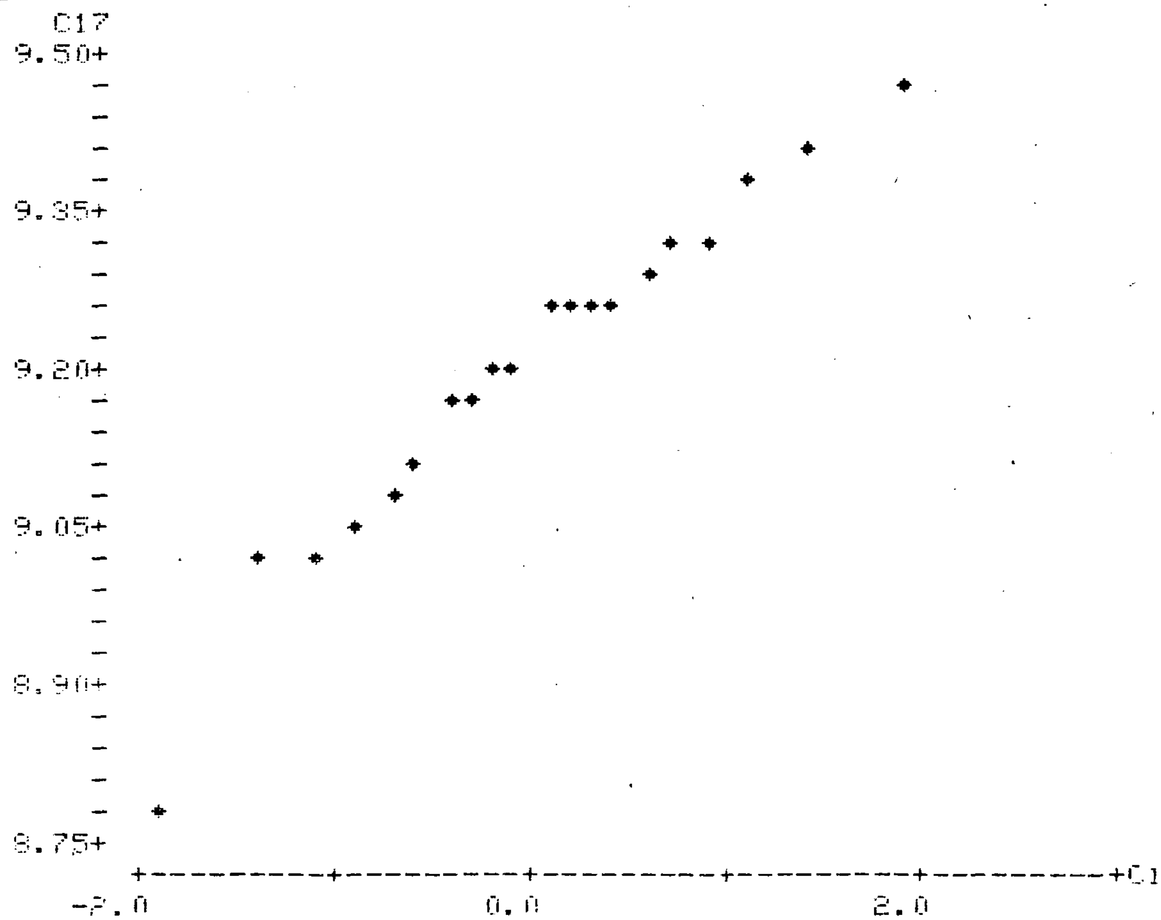
NSCD MOR SPRUCE-FIR THINNINGS C27 C1

PLOT C27 C1



NSCD NATURAL LOG MOR SPRUCE-FIR THINNINGS C17 C1

PLOT C17 C1



APPENDIX B

SMALL CLEAR BENDING TEST

ANALYSIS OF VARIANCE

```
--
? ONEW MOE FOR SMALL CLEAR BENDING TEST FOR ALL DATA C3 C1

ANALYSIS OF VARIANCE

DUE TO          DF          SS       MS=SS/DF        F-RATIO
FACTOR           6************************              41.07
ERROR          121***********55263433726.
TOTAL          127************

LEVEL          N          MEAN          ST. DEV.
1             14       1474005.          229076.
2             16       1627486.          312375.
3             18       1360455.          166351.
4             20       2023804.          329578.
5             20       1140682.          113209.
6             20        965097.          138814.
7             20       1320139.          271170.

POOLED ST. DEV. =        235082.

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
1                          I****I****I
2                                I****I****I
3                      I***I****I
4                                                   I***I***I
5             I****I***I
6       I***I****I
7                     I***I***I
       +---------+---------+---------+---------+---------+---------+
  850000.   1100000.  1350000.  1600000.  1850000.  2100000.  2350000.
```

--

ONEW MOR FOR SMALL CLEAR BENDING TEST FOR ALL DATA C2 C1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	369877838.	61646306.	37.13
ERROR	121	200869150.	1660076.	
TOTAL	127	570746988.		

LEVEL	N	MEAN	ST. DEV.
1	14	10889.	1373.
2	14	10961.	1062.
3	14	10750.	1295.
4	20	12492.	1715.
5	20	7929.	1030.
6	20	[illegible]	791.
7	20	10023.	1504.

POOLED ST. DEV. = 1288.

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
1                                 I****I****I
2                                  I****I***I
3                                 I***I****I
4                                                I***I***I
5           I***I***I
6        I***I***I
7                            I***I***I
      +---------+---------+---------+---------+---------+---------+
   6500.     7900.     9300.    10700.    12100.    13500.    14900.
```

```
ONEW MOE FOR ALL PINE DATA EXCLUDING PINE THINNINGS C10 C20

 ANALYSIS OF VARIANCE

 DUE TO          DF          SS       MS=SS/DF       F-RATIO
 FACTOR           2************************            5.21
 ERROR           45************58139929003.
 TOTAL           47************

 LEVEL           N           MEAN        ST. DEV.
 1              14       1474005.        229076.
 2              16       1627486.        312375.
 3              18       1360455.        166351.

 POOLED ST. DEV. =      241122.

 INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
 (BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
 1                   I************I************I
 2                                         I***********I***********I
 3           I**********I**********I
       +---------+---------+---------+---------+---------+---------+
  1200000.  1300000.  1400000.  1500000.  1600000.  1700000.  1800000.

 --


ONEW MOR FOR ALL PINE DATA EXCLUDING PINE THINNINGS C30 C20

 ANALYSIS OF VARIANCE

 DUE TO          DF          SS       MS=SS/DF       F-RATIO
 FACTOR           2      393377.      196689.           .13
 ERROR           45    69942181.     1554271.
 TOTAL           47    70335558.

 LEVEL           N           MEAN        ST. DEV.
 1              14         10889.          1373.
 2              16         10961.          1062.
 3              18         10750.          1295.

 POOLED ST. DEV. =         1247.

 INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
 (BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
 1                I*********************I*********************I
 2                  I*********************I*********************I
 3              I*******************I*******************I
       +---------+---------+---------+---------+---------+---------+
     9900.    10200.    10500.    10800.    11100.    11400.    11700.

 --
```

```
? ONEW MOE FOR SPRUCE DATA EXCLUDING SPRUCE-FIR THINNINGS C45 C46

ANALYSIS OF VARIANCE

DUE TO          DF          SS        MS=SS/DF        F-RATIO
FACTOR           1************************            15.08
ERROR           38************16042841408.
TOTAL           39************


LEVEL          N            MEAN          ST. DEV.
5             20        1140623.          113209.
6             20         985097.          138814.

POOLED ST. DEV. =        126660.

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
        +---------+---------+---------+---------+---------+---------+
5                                      I********I*********I
6            I********I*********I
        +---------+---------+---------+---------+---------+---------+
   900000.   960000.  1020000.  1080000.  1140000.  1200000.  1260000.

--
```

```
 ONEW MOR FOR ALL SPRUCE DATA EXCLUDING SPRUCE-FIR THINNINGS C45 C46

ANALYSIS OF VARIANCE

DUE TO          DF          SS        MS=SS/DF        F-RATIO
FACTOR           1     1821284.      1821284.            2.16
ERROR           38    32061232.       843717.
TOTAL           39    33882516.


LEVEL          N            MEAN          ST. DEV.
5             20           7928.            1030.
6             20           7502.             791.

POOLED ST. DEV. =           919.

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
        +---------+---------+---------+---------+---------+---------+
5                         I****************I****************I
6        I****************I****************I
        +---------+---------+---------+---------+---------+---------+
    7050.     7300.     7550.     7800.     8050.     8300.     8550.

--
```

ONEW SMALL CLEAR BENDING TESTS MOE FOR ALL DATA WITH FIR SEPARATED C2

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	7	372209417.	53172774.	32.14
ERROR	120	198537571.	1654480.	
TOTAL	127	570746988.		

LEVEL	N	MEAN	ST. DEV.
1	14	10889.	1373.
2	16	10961.	1062.
3	18	10750.	1295.
4	20	12492.	1715.
5	20	7928.	1030.
6	20	7502.	791.
7	17	10166.	1545.
8	3	9210.	1106.

POOLED ST. DEV. = 1286.

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
          +---------+---------+---------+---------+---------+---------+
1                                I****I****I
2                                 I****I***I
3                                I***I****I
4                                             I***I***I
5               I***I***I
6            I***I***I
7                            I***I****I
8                 I*********I*********I
          +---------+---------+---------+---------+---------+---------+
        6500.     7900.     9300.    10700.    12100.    13500.    14900.
```

--

```
ONEW MOR SMALL CLEAR BENDING TEST FOR ALL DATA WITH FIR SEPARATED C3 C1

 ANALYSIS OF VARIANCE

 DUE TO          DF          SS       MS=SS/DF        F-RATIO
 FACTOR            7*************************          35.26
 ERROR           120************55350430421.
 TOTAL           127************

 LEVEL         N           MEAN         ST. DEV.
 1            14        1474005.        229076.
 2            16        1627486.        312375.
 3            19        1360455.        166351.
 4            20        2088803.        329578.
 5            20        1140623.        113209.
 6            20         985097.        138814.
 7            17        1340026.        290007.
 8             3        1207444.         57655.

 POOLED ST. DEV. =       235267.

 INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
 (BASED ON POOLED STANDARD DEVIATION)
         +---------+---------+---------+---------+---------+---------+---
 1                           I****I****I
 2                                 I****I****I
 3                       I***I****I
 4                                                 I***I***I
 5               I****I***I
 6         I***:****I
 7                      I****I***I
 8             I*********I*********I
         +---------+---------+---------+---------+---------+---------+
    850000.  1100000.  1350000.  1600000.  1850000.  2100000.  2350000.

 --
```

APPENDIX C

TOUGHNESS TEST

TOUGHNESS TEST

COLUMN 1 = LINE NUMBERS

COLUMN 2 = MATERIAL CLASS (1 = LIVE LODGEBOLE, 2 = DEAD PINE <5 YRS., 3 = DEAD PINE 5+ YRS., 4 = PINE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE THINNINGS, 8 = FIR THINNINGS)

COLUMN 3 = ENERGY ABSORBED (IN-LBS.)

```
00100 1 98.51
00110 1 84.57
00120 1 63.40
00130 1 93.48
00140 1116.32
00150 1 95.92
00160 1118.57
00170 1100.01
00180 1 95.26
00190 1119.89
00200 1108.04
00210 1140.86
00220 1 68.27
00230 1125.27
00240 1103.03
00250 2 75.46
00260 2 57.56
00270 2102.26
00280 2 95.37
00290 2 76.85
00300 2 75.84
00310 2 98.88
00320 2 73.15
00330 2102.38
00340 2112.76
00350 2 72.61
00360 2106.63
00370 2 69.12
00380 2108.41
00390 2 92.90
00400 2 56.64
00410 2 96.48
00420 2 86.27
00430 2 53.84
00440 2 69.74
00450 3111.73
00460 3 74.43
00470 3121.76
00480 3137.83
00490 3 95.96
00500 3132.94
00510 3103.16
00520 3102.90
00530 3 95.37
00540 3 42.62
00550 3108.83
00560 3 71.50
00570 3128.30
00580 3 84.88
00590 3 73.33
00600 3 92.69
00610 3 85.94
00620 4146.01
00630 4137.20
00640 4102.64
00650 4146.01
00660 4 91.76
00670 4172.14
00680 4144.34
00690 4 90.04
00700 4143.80
00710 4144.69
00720 4116.00
00730 4103.15
00740 4173.52
00750 4127.82
00760 4103.40
00770 4112.01
00780 4 81.70
00790 4 46.09
00800 4129.59
00810 4115.18
00820 4161.07
00830 4177.48
00840 5 74.53
00850 5 97.17
00860 5 80.79
00870 5104.71
00880 5 82.67
00890 5100.48
00900 5 81.29
00910 5 88.16
00920 5 81.60
00930 5107.61
00940 5 67.08
00950 5157.54
00960 5121.15
00970 5 70.26
00980 5123.73
00990 5105.22
01000 5 87.91
01010 5 50.21
01020 5 58.46
01030 5 76.95
01040 5 79.52
01050 6 75.94
01060 6 97.05
01070 6 67.13
01080 6 50.52
01090 6 69.30
01100 6 33.20
01110 6 50.65
01120 6 89.67
01130 6 80.68
01140 6 82.25
01150 6 59.39
01160 6 53.63
01170 6 64.60
01180 6 69.21
01190 6 68.26
01200 6 29.50
01210 6 40.13
01220 6 79.99
01230 6199.04
01240 6 57.72
01250 6 81.29
01260 7106.82
01270 8 64.52
01280 8 88.36
01290 7105.66
01300 7 90.73
01310 7163.06
01320 7104.92
01330 7115.73
01340 7116.31
01350 7106.72
01360 7 76.03
01370 7114.56
01380 7138.26
01390 8 75.00
01400 7134.09
01410 8113.02
01420 7155.30
01430 7103.28
01440 7106.70
01450 7136.85
```

APPENDIX C

TOUGHNESS TEST

TEST FOR NORMALITY

HISTOGRAMS

AND

NORMAL SCORES VERSUS DATA PLOTS

HIST TOUGHNESS FOR LIVE PINE C12

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
60.	1	*
70.	1	*
80.	1	*
90.	1	*
100.	5	*****
110.	1	*
120.	3	***
130.	1	*
140.	1	*

--

? HIST TOUGHNESS FOR DEAD PINE (5 YRS <) C22

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
55.	2	**
60.	1	*
65.	0	
70.	2	**
75.	5	*****
80.	0	
85.	1	*
90.	0	
95.	3	***
100.	3	***
105.	1	*
110.	1	*
115.	1	*

--

? HIST TOUGHNESS FOR DEAD PINE (5+ YRS) C23

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
40.	1	*
50.	0	
60.	0	
70.	3	***
80.	1	*
90.	2	**
100.	4	****
110.	2	**
120.	1	*
130.	2	**
140.	1	*

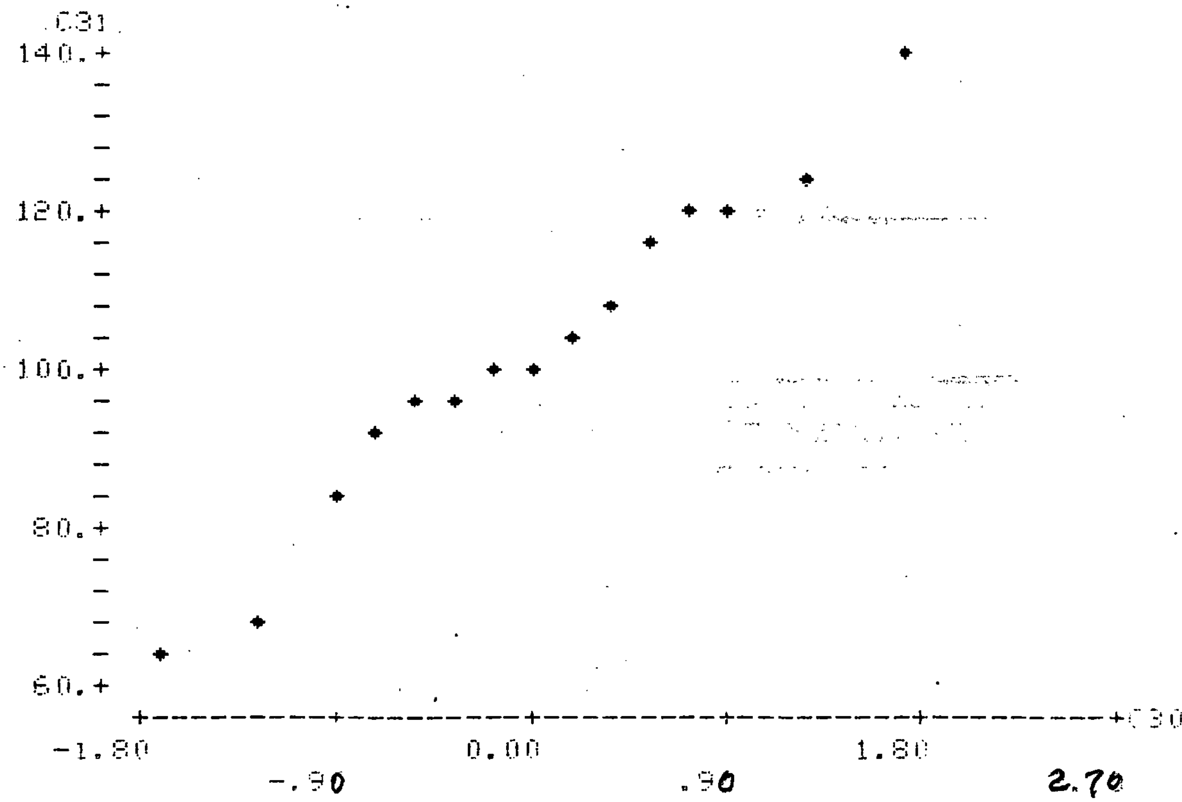
--

? HIST TOUGHNESS FOR PINE THINNING C24

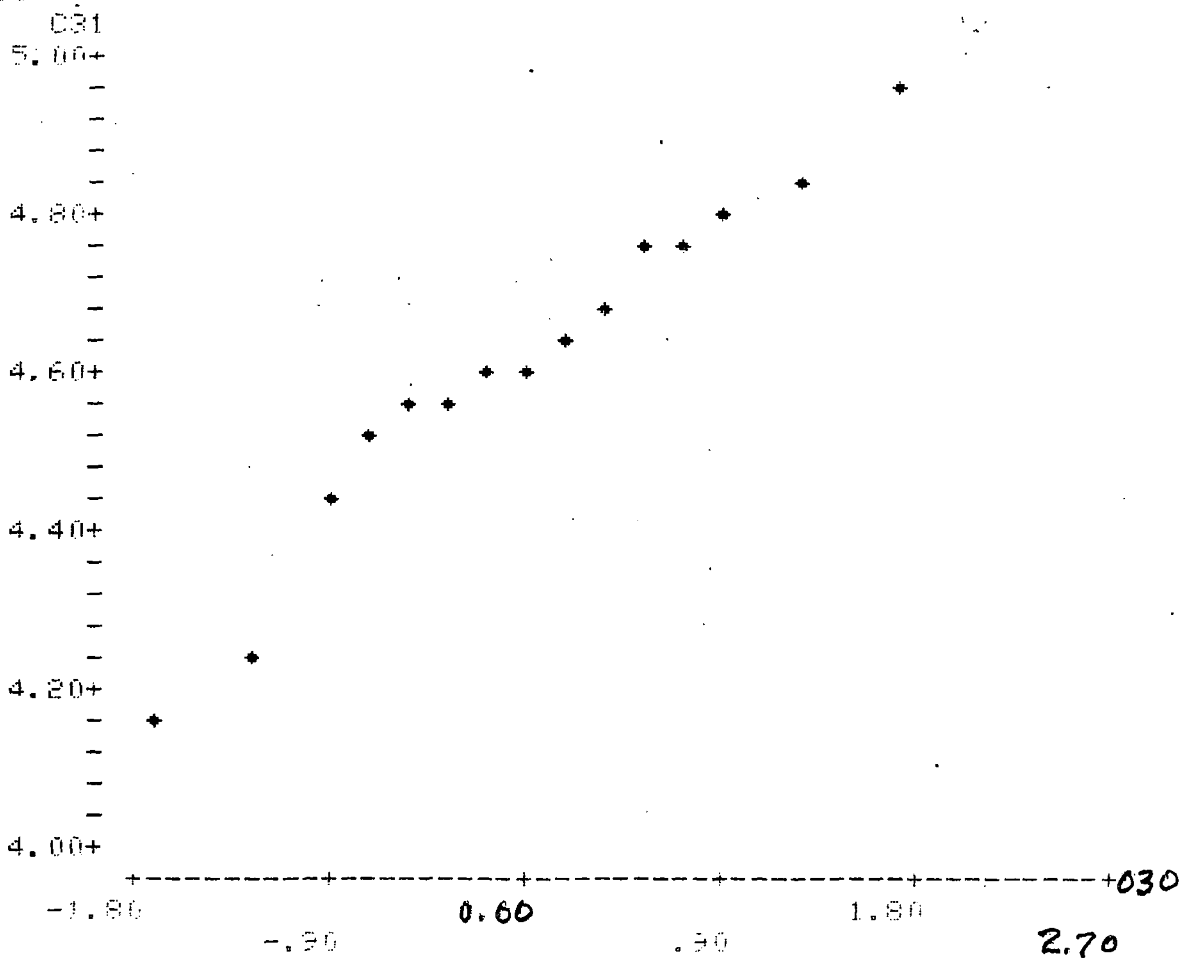
MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
40.	1	*
60.	6	
80.	1	*
100.	5	*****
120.	5	*****
140.	6	******
160.	1	*
180.	3	***

```
? HIST TOUGHNESS FOR LIVE SPRUCE C25

    MIDDLE OF   NUMBER OF
    INTERVAL    OBSERVATIONS
       50.         1     *
       60.         1     *
       70.         3     ***
       80.         6     ******
       90.         2     **
      100.         3     ***
      110.         2     **
      120.         2     **
      130.         0
      140.         0
      150.         0
      160.         1     *

--
? HIST TOUGHNESS FOR DEAD SPRUCE C26

    MIDDLE OF   NUMBER OF
    INTERVAL    OBSERVATIONS
       20.         1     *
       40.         2     **
       60.        10     **********
       80.         6     ******
      100.         1     *
      120.         0
      140.         0
      160.         0
      180.         0
      200.         1     *

--
? HIST TOUGHNESS FOR SPRUCE THINNINGS C27

    MIDDLE OF   NUMBER OF
    INTERVAL    OBSERVATIONS
       60.         1     *
       70.         0
       80.         2     **
       90.         2     **
      100.         2     **
      110.         6     ******
      120.         2     **
      130.         1     *
      140.         2     **
      150.         0
      160.         2     **

--
?
```

```
HIST TOUGHNESS LIVE PINE C31

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
       60.         1     *
       70.         1     *
       80.         1     *
       90.         1     *
      100.         5     *****
      110.         1     *
      120.         3     ***
      130.         1     *
      140.         1     *

 --
? NSCO C31 C30
 --
? PLOT C31 C30
```

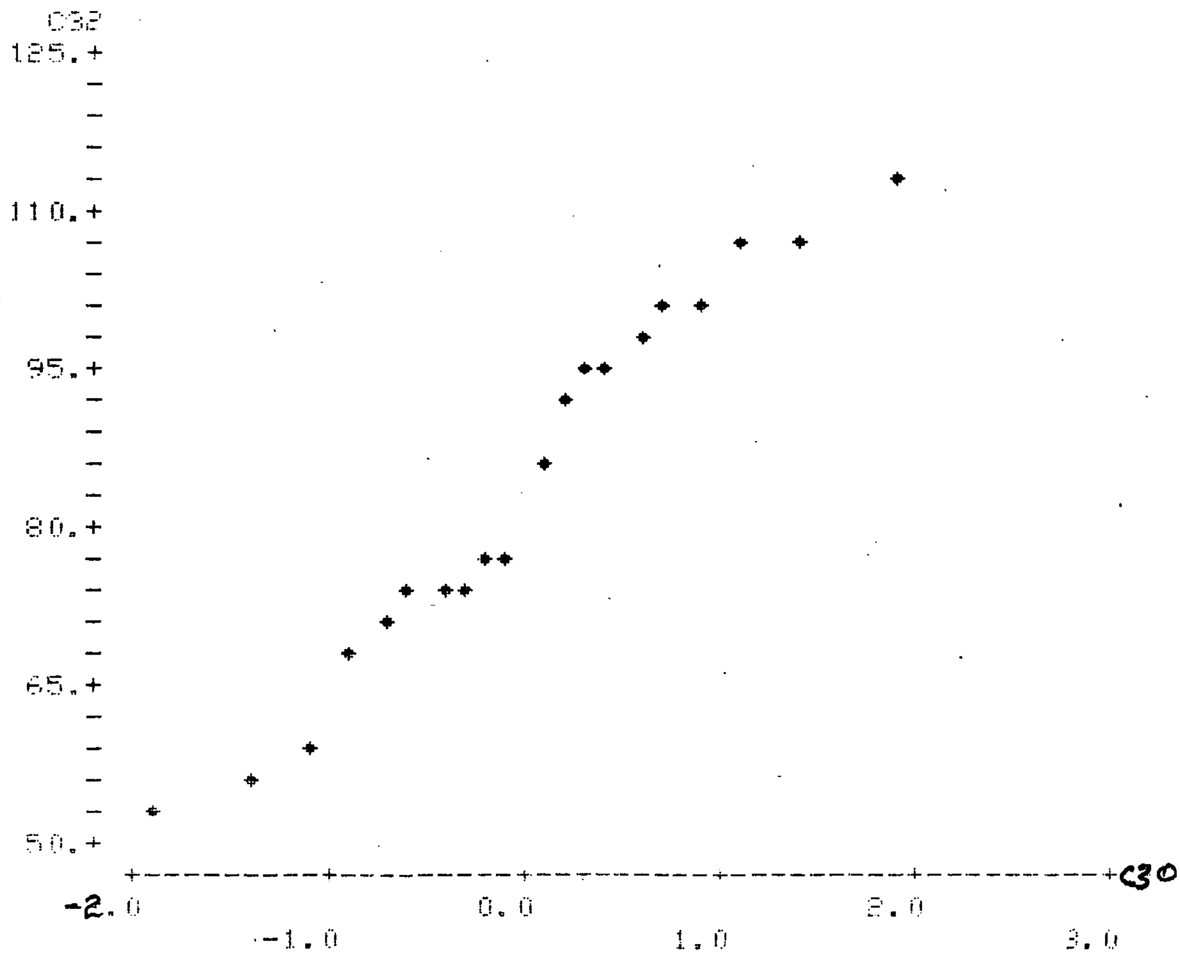


```
--
? HIST LOG TOUGHNESS LIVE PINE C31

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
      4.1           1      *
      4.2           1      *
      4.3           0
      4.4           1      *
      4.5           1      *
      4.6           5      *****
      4.7           1      *
      4.8           4      ****
      4.9           1      *

--
? NSCO C31 C30
--
? PLOT C31 C30
```

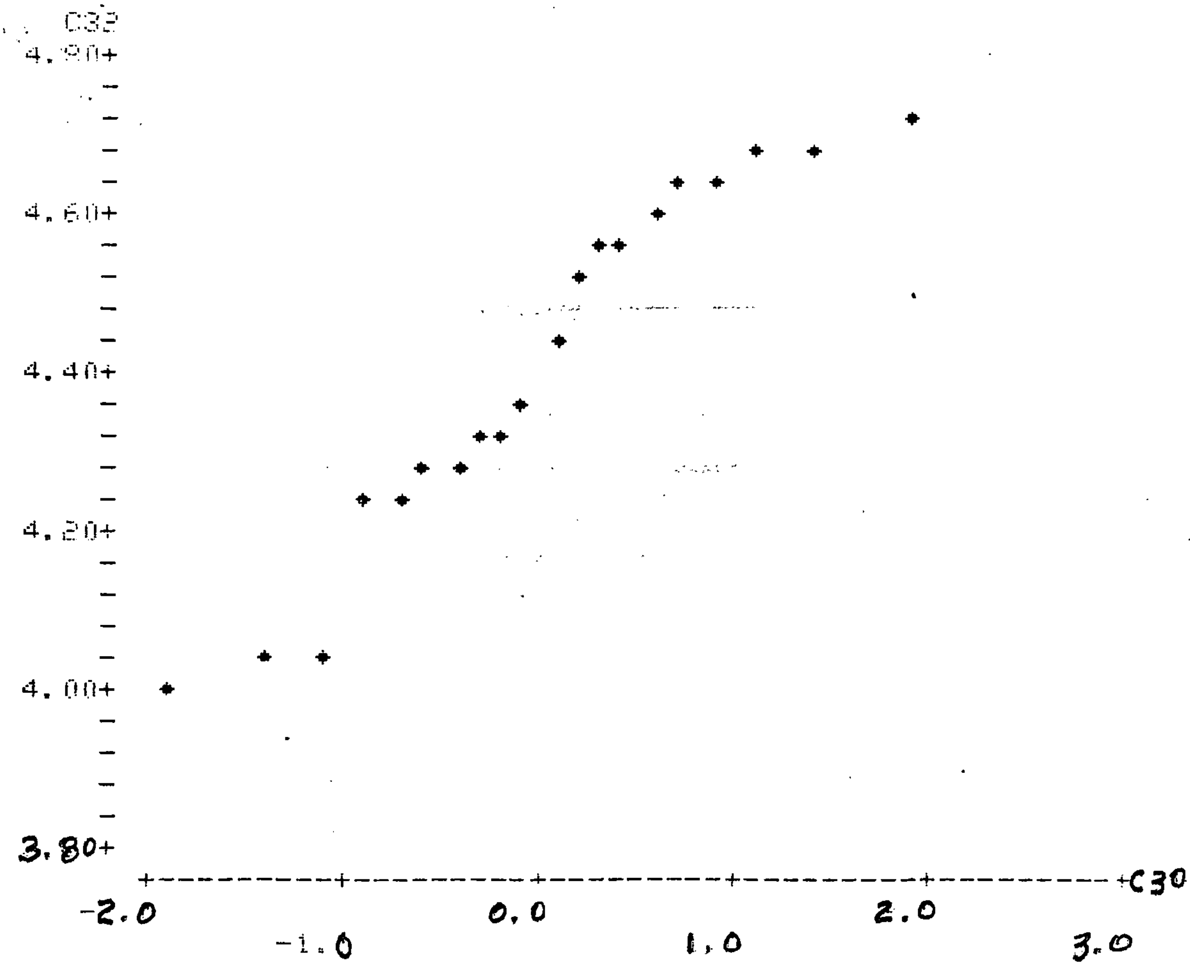


--

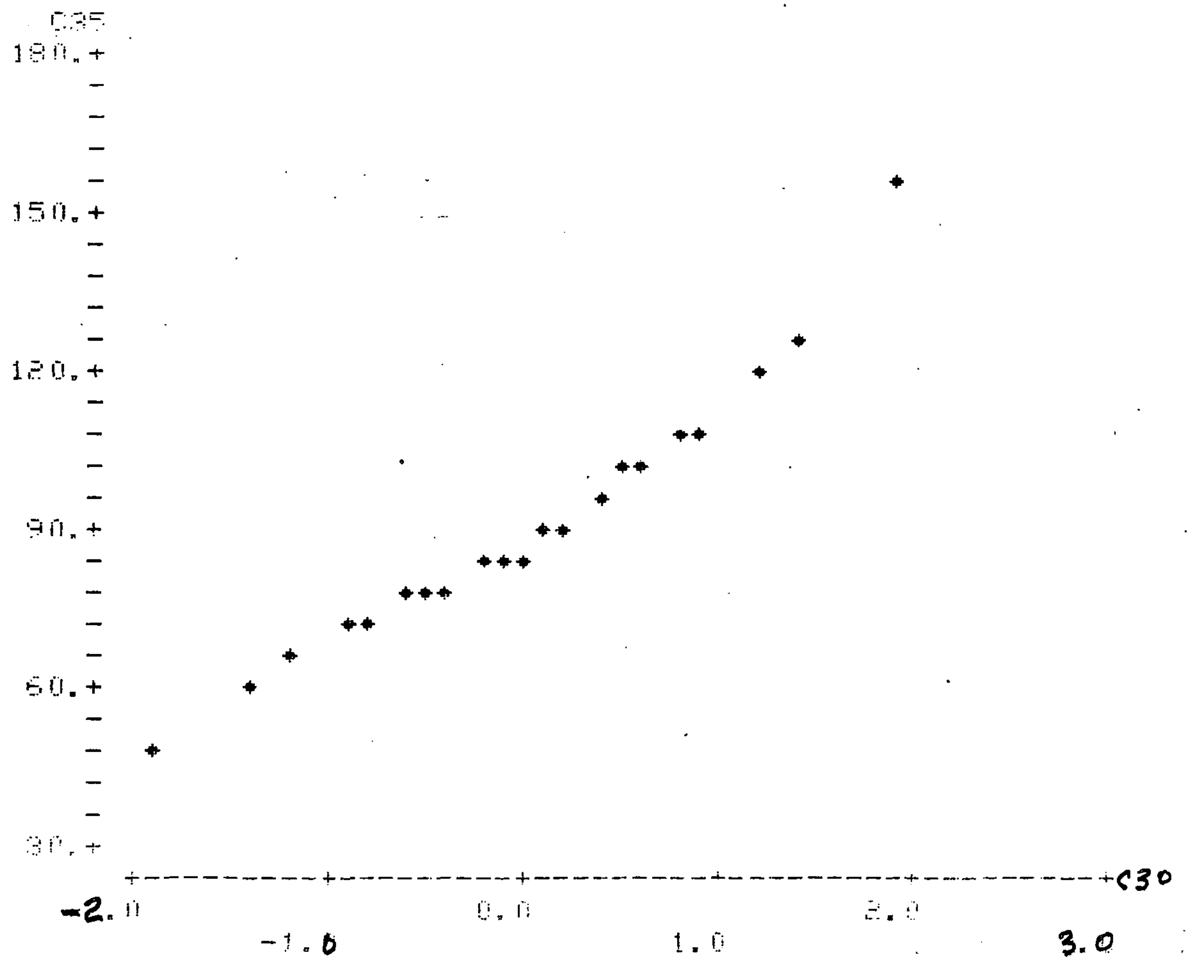
```
HIST DEAD PINE (<5 YRS) C32

   MIDDLE OF     NUMBER OF
   INTERVAL      OBSERVATIONS
       55.          2        **
       60.          1        *
       65.          0
       70.          2        **
       75.          5        *****
       80.          0
       85.          1        *
       90.          0
       95.          3        ***
      100.          3        ***
      105.          1        *
      110.          1        *
      115.          1        *

--
? NSCO C32 C30
--
? PLOT C32 C30
```



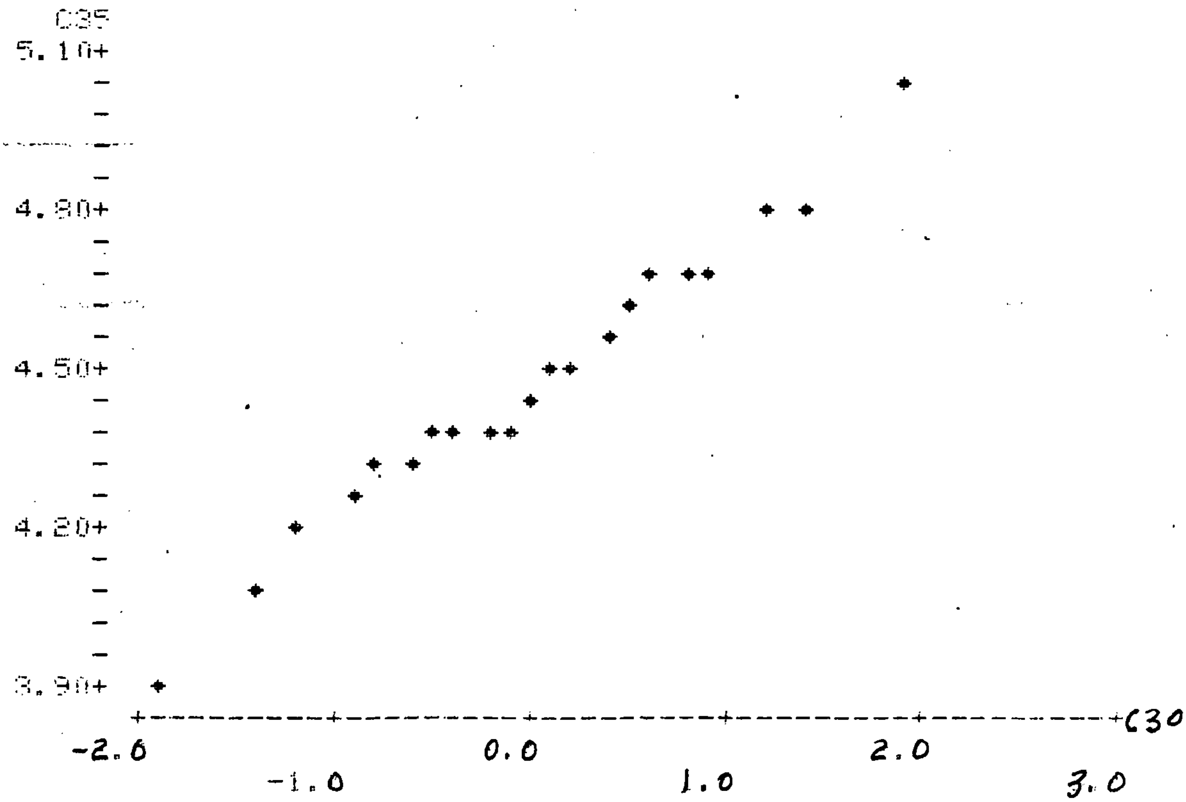
```
--
? HIST LOG TOUGHNESS FOR DEAD PINE (<5 YRS) C32

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
        4.0         2      **
        4.1         1      *
        4.2         2      **
        4.3         5      *****
        4.4         0
        4.5         2      **
        4.6         5      *****
        4.7         3      ***

--
? NSCO C32 C30
--
? PLOT C32 C30
```



```
HIST LIVE SPRUCE C35

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
       50.          1       *
       60.          1       *
       70.          3       ***
       80.          6       ******
       90.          2       **
      100.          3       ***
      110.          2       **
      120.          2       **
      130.          0
      140.          0
      150.          0
      160.          1       *

 --
? NSCO C35 C30
 --
? PLOT C35 C30
```



```
--
? HIST LOG TOUGHNESS LIVE SPRUCE C35
    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
       3.9          1     *
       4.0          0
       4.1          1     *
       4.2          1     *
       4.3          3     ***
       4.4          5     *****
       4.5          2     **
       4.6          2     **
       4.7          3     ***
       4.8          2     **
       4.9          0
       5.0          0
       5.1          1     *
--
? NSCO C35 C30
--
? PLOT C35 C30
```



--

APPENDIX C

TOUGHNESS TEST

ANALYSIS OF VARIANCE

LEVELS: 1 = LIVE LODGEPOLE, 2 = DEAD PINE LESS THAN 5 YRS., 3 = DEAD PINE 5+ YRS., 4 = PINE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE THINNINGS, 8 = FIR THINNINGS

ONEW TOUGHNESS TEST FOR ALL DATA WITH FIR SEPARATED C2 C1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	7	43590.	6227.	8.86
ERROR	129	89918.	702.	
TOTAL	136	133507.		

LEVEL	N	MEAN	ST. DEV.
1	15	102.1	20.7
2	20	84.2	18.4
3	17	97.9	24.9
4	22	125.7	33.1
5	21	90.3	24.4
6	21	71.4	34.3
7	16	117.2	22.9
8	4	85.2	20.9

POOLED ST. DEV. = 26.5

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
1                              I*********I*********I
2                     I*******I********I
3                            I*********I********I
4                                                I*******I********I
5                        I********I*******I
6          I********I********I
7                                         I********I*********I
8          I*****************I******************I
      +---------+---------+---------+---------+---------+---------+
     55.       70.       85.       100.      115.      130.      145.
```

```
 ONEW TOUGHNESS FOR PINE DATA WITH THINNINGS REMOVED C12 C11

ANALYSIS OF VARIANCE

DUE TO          DF         SS       MS=SS/DF     F-RATIO
FACTOR           2       3176.       1588.         3.48
ERROR           49      22344.        456.
TOTAL           51      25520.

LEVEL          N           MEAN       ST. DEV.
1             15          102.1         20.7
2             80           84.2         18.4
3             17           97.9         24.9

POOLED ST. DEV. =          21.4

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
        +---------+---------+---------+---------+---------+---------
1                               I***********I************)
2          I**********I*********I
3                           I***********I**********I
        +---------+---------+---------+---------+---------+---------
     72.0      81.0      90.0      99.0      108.0     117.0     126.0

--
? ONEW TOUGHNESS FOR SPRUCE DATA WITH THINNINGS REMOVED C22 C21

ANALYSIS OF VARIANCE

DUE TO          DF         SS       MS=SS/DF     F-RATIO
FACTOR           1       3769.       3769.         4.26
ERROR           40      35362.        884.
TOTAL           41      39131.

LEVEL          N           MEAN       ST. DEV.
5             21           90.3         24.4
6             21           71.4         34.3

POOLED ST. DEV. =          29.7

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
        +---------+---------+---------+---------+---------+---------
5                                    I************I************)
6                 I************I*************)
        +---------+---------+---------+---------+---------+---------
     50.       60.       70.       80.       90.       100.      110.

--
```

APPENDIX D

GLUE SHEAR BLOCK TEST

GLUE SHEAR BLOCK TEST

COLUMN 1 = LINE NUMBERS
COLUMN 2 = MATERIAL CLASS (1 = LIVE LODGEPOLE, 2 = DEAD PINE <5 YRS., 3 DEAD PINE 5+ YRS., 4 PINE THINNINGS, 5 = LIVE SPRUCE, 6 DEAD SPRUCE, 7 = SPRUCE-FIR THINNINGS)
COLUMN 3 = MOISTURE CONTENT (%)
COLUMN 4 = SHEAR FORCE POUNDS PER SQUARE INCH
COLUMN 5 = GLUE BATCH
COLUMN 6 = CLOSED ASSEMBLY TIME (MINUTES)

00100	1	10.5	959	1	15
00110	1	10.1	1060	3	15
00120	1	9.3	930	5	15
00130	1	9.7	1398	3	5
00140	1	10.3	1244	3	5
00150	1	8.5	1111	5	5
00160	1	11.0	1338	7	15
00170	1	11.4	1392	1	5
00180	1	9.1	1110	7	5
00190	1	10.4	1272	7	5
00200	1	10.6	1052	7	5
00210	1	9.1	1240	3	15
00220	1	10.3	1454	3	5
00230	1	11.1	1237	7	15
00240	1	10.3	1372	3	15
00250	1	9.4	1299	1	5
00270	1	10.8	1054	7	15
00280	1	10.0	1137	5	15
00290	2	10.4	975	6	15
00300	2	9.5	1136	7	5
00310	2	11.0	1056	1	5
00320	2	9.7	941	3	15
00330	2	8.5	1478	5	15
00340	2	10.1	1400	3	5
00350	2	11.0	1517	7	15
00360	2	9.2	1214	5	5
00370	2	9.8	1068	5	15
00380	2	8.3	1307	7	5
00390	2	9.2	1335	5	15
00400	2	11.1	1264	2	15
00410	2	10.6	1170	7	15
00420	2	10.7	1110	6	5
00430	2	10.4	919	2	5
00440	2	10.0	1199	5	5
00450	2	10.7	904	2	15
00460	2	8.8	1384	5	5
00470	3	7.5	1203	9	15
00480	3	10.5	1420	6	5
00490	3	9.5	1274	6	15
00500	3	10.5	1342	2	15

00510	3	10.6	1236	1	5
00520	3	10.9	1139	7	15
00530	3	9.7	1270	3	15
00540	3	14.2	1024	7	5
00550	3	10.7	1547	7	5
00560	3	10.6	1261	8	15
00570	3	8.7	1383	8	5
00580	3	9.2	747	3	5
00590	3	9.3	1461	6	5
00600	3	8.4	1383	9	5
00610	3	11.9	1243	1	15
00620	3	11.0	1086	7	15
00630	3	9.0	1251	5	15
00660	3	9.4	1310	5	5
00670	4	11.7	1315	2	15
00680	4	9.5	1434	4	5
00690	4	10.3	1415	3	5
00700	4	10.7	1202	6	15
00710	4	10.5	1337	6	15
00720	4	8.8	919	5	15
00730	4	9.8	1348	5	5
00740	4	11.2	1045	8	15
00750	4	10.6	1329	3	15
00760	4	11.9	1575	6	15
00770	4	9.5	1257	6	5
00780	4	12.0	1662	2	5
00790	4	10.6	1224	6	15
00800	4	11.1	1307	6	5
00810	4	9.7	1188	6	5
00820	4	10.7	1169	6	5
00830	4	11.1	1244	4	15
00840	4	6.8	1020	8	5
00870	5	9.9	858	3	5
00880	5	10.9	1258	2	15
00890	5	10.0	955	2	5
00900	5	9.2	1075	5	5
00910	5	12.0	1215	1	5
00920	5	11.2	1199	1	15
00930	5	11.0	1065	3	15
00940	5	10.4	1214	7	15
00950	5	11.3	1102	7	5
00960	5	10.9	940	9	5
00970	5	8.8	1181	5	15
00980	5	10.3	1178	9	15
00990	5	11.2	964	9	15
01000	5	13.7	1216	8	15
01010	5	9.3	912	9	5
01020	5	14.3	1172	8	15
01030	5	9.9	1231	8	5
01060	5	12.8	1132	8	5
01070	6	6.6	1310	9	5
01080	6	10.3	1254	6	5
01090	6	6.5	1289	9	15
01100	6	7.2	1209	8	5
01110	6	11.4	881	1	15
01120	6	9.9	948	3	5
01130	6	5.8	1123	8	5
01140	6	8.2	1333	8	15
01150	6	12.4	1151	1	15
01160	6	7.4	1157	8	15
01170	6	10.5	1304	4	15
01180	6	10.6	1189	6	15
01190	6	9.9	1063	4	15
01200	6	10.4	1249	4	15
01210	6	10.8	1055	1	5
01240	6	7.2	1045	4	5
01250	6	9.2	910	4	5
01260	6	8.6	981	4	5
01270	7	7.7	1252	8	15
01280	7	9.6	1216	8	15
01290	7	7.7	1188	8	5
01300	7	9.3	889	4	15
01310	7	11.5	1207	8	5
01320	7	10.0	1000	4	5
01330	7	10.8	1347	2	5
01350	7	10.4	1241	2	15
01360	7	10.1	0924	2	15
01370	7	10.4	1153	2	5
01380	7	11.9	1261	1	15
01390	7	9.9	1140	4	5
01400	7	8.4	1204	4	15
01420	7	10.5	1386	1	5
01430	7	11.9	1365	4	15
01440	7	10.6	1202	2	5
01450	7	07.3	1167	4	15
01460	7	10.2	1190	4	5

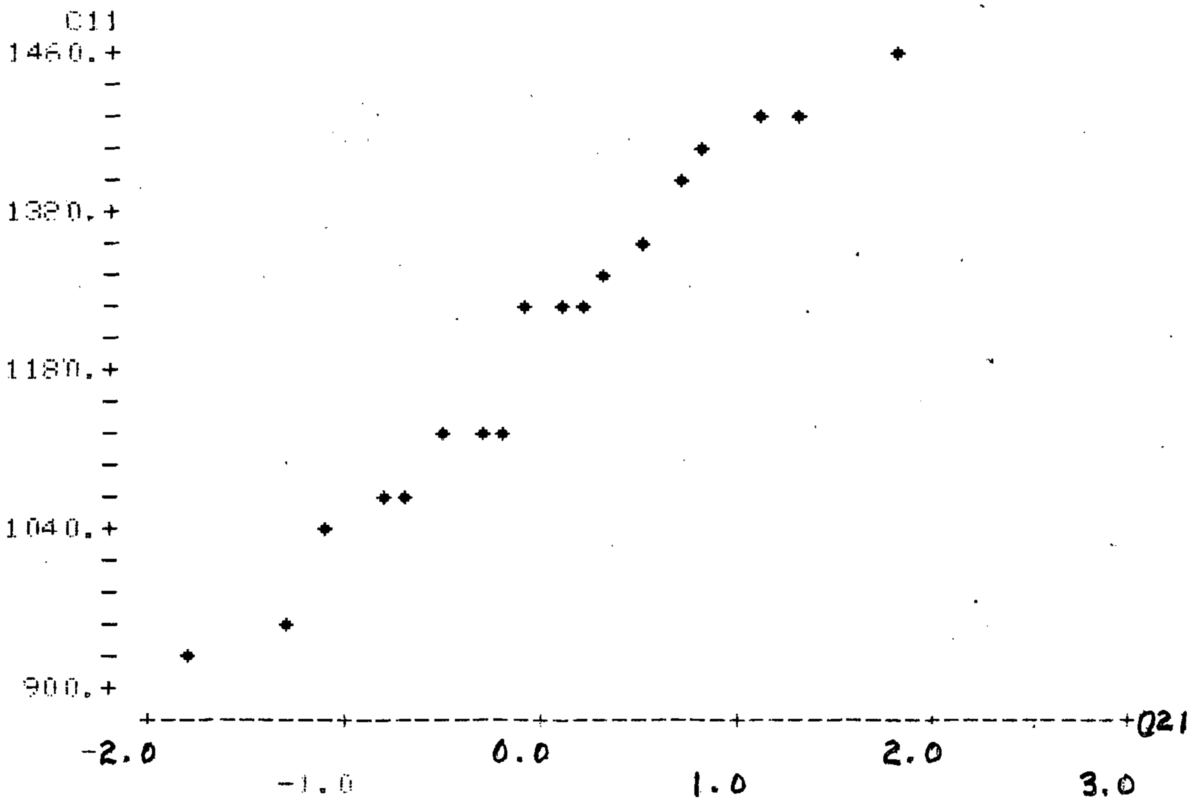
APPENDIX D

GLUE SHEAR BLOCK TEST

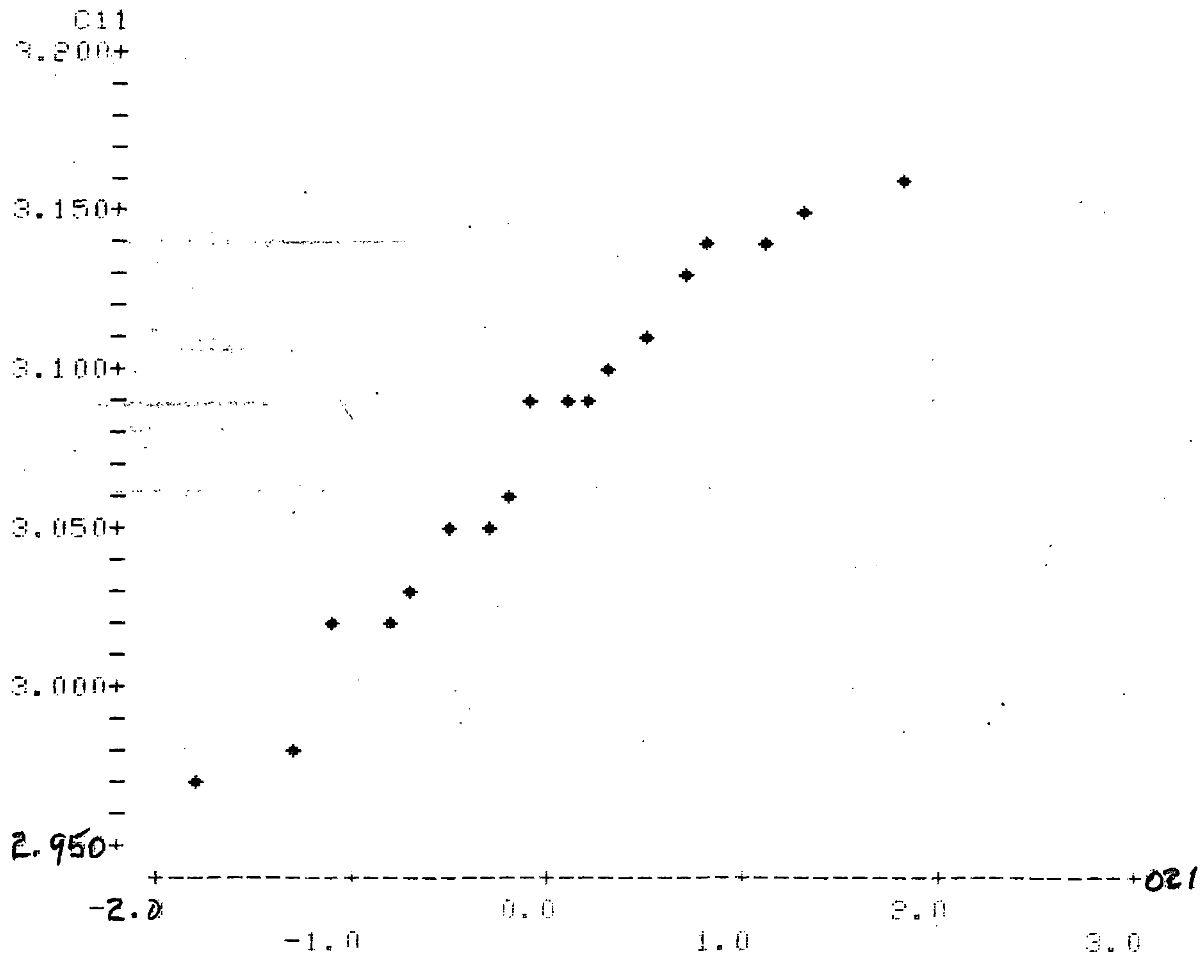
TEST FOR NORMALITY

HISTOGRAMS
AND
NORMAL SCORES VERSUS DATA PLOTS

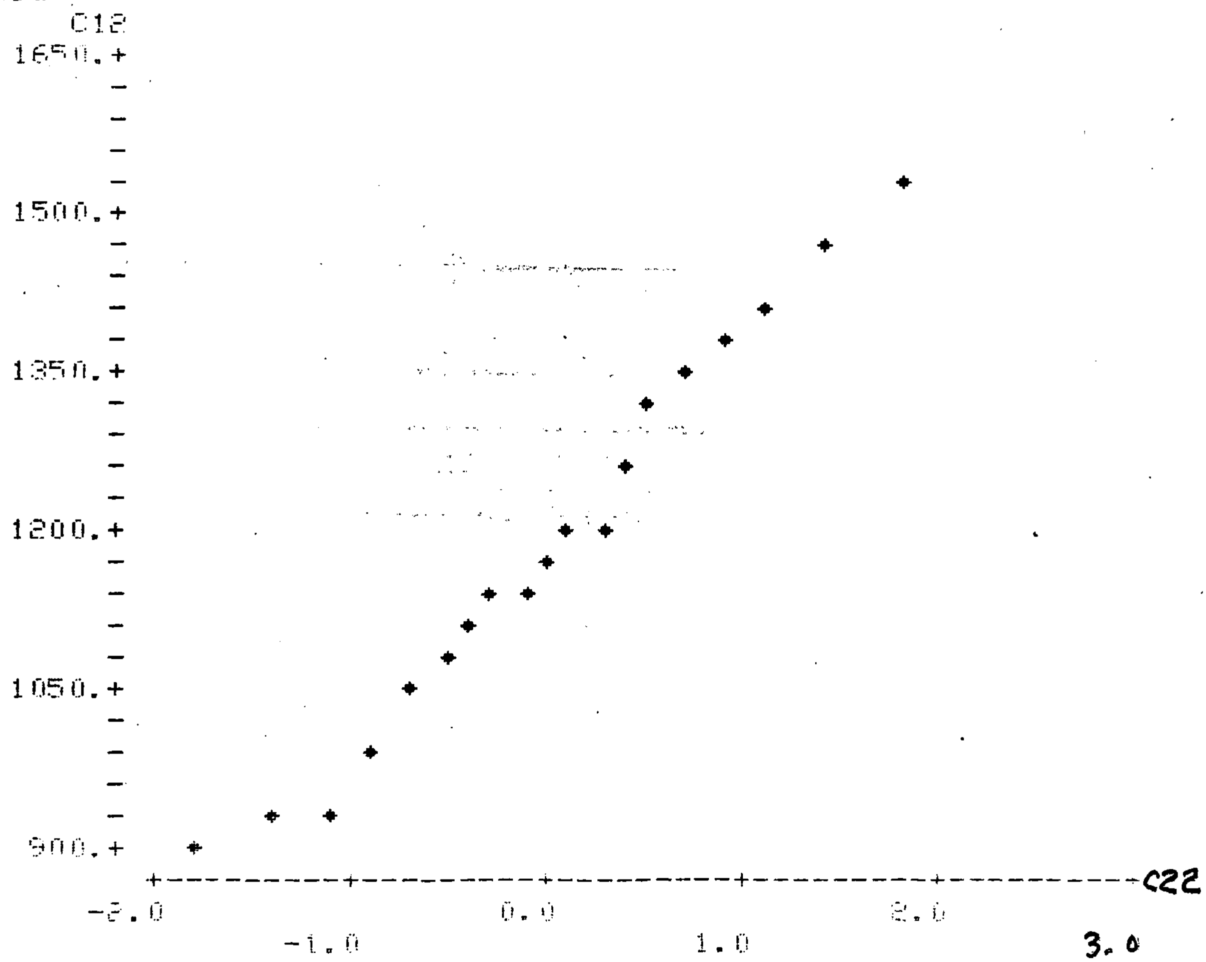
```
HIST GLUE STRENGTH FOR LIVE PINE C11

     MIDDLE OF    NUMBER OF
     INTERVAL     OBSERVATIONS
        950.          2     **
       1000.          0
       1050.          3     ***
       1100.          2     **
       1150.          1     *
       1200.          0
       1250.          4     ****
       1300.          1     *
       1350.          2     **
       1400.          2     **
       1450.          1     *

 --
? NSCO C11 C21
 --
? PLOT C11 C21
```



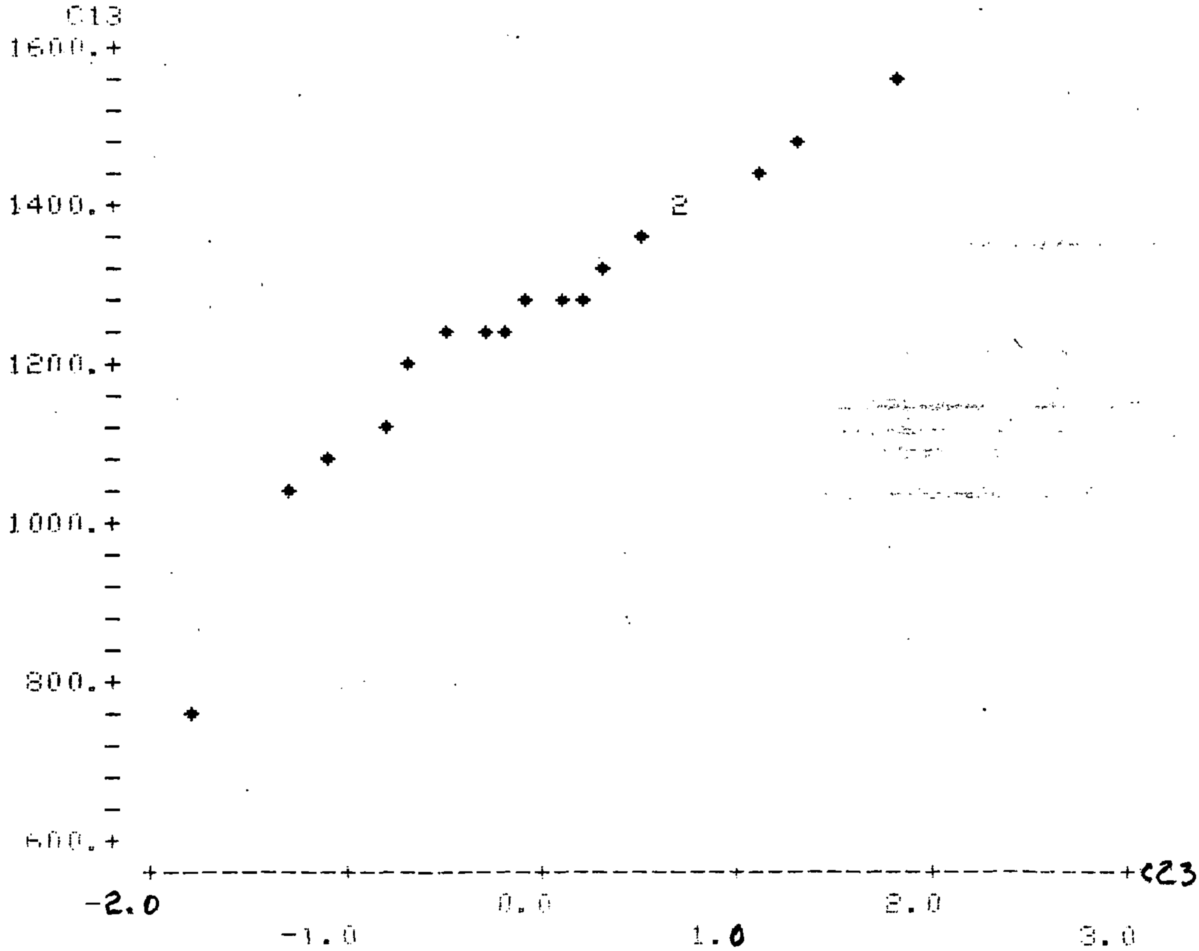
```
HIST LOG GLUE STRENGTH FOR LIVE PINE C11

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
      2.96        1      *
      2.98        1      *
      3.00        0
      3.02        3      ***
      3.04        2      **
      3.06        1      *
      3.08        0
      3.10        4      ****
      3.12        2      **
      3.14        3      ***
      3.16        1      *

--
? NSCO C11 C21
--
? PLOT C11 C21
```



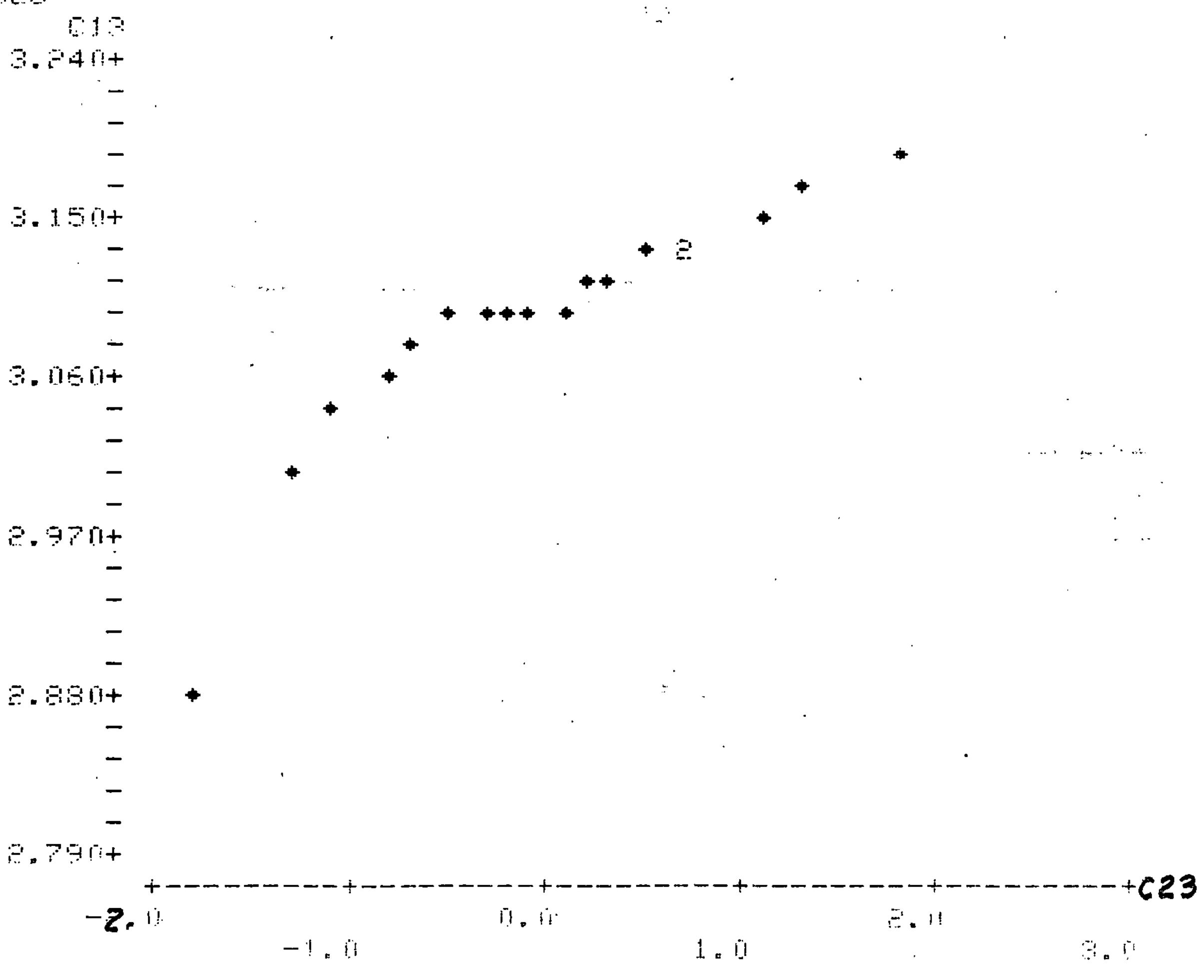
```
HIST GLUE STRENGTH FOR DEAD PINE <5 YEARS <> C12

  MIDDLE OF    NUMBER OF
  INTERVAL     OBSERVATIONS
     900.         3       ***
    1000.         1       *
    1100.         5       *****
    1200.         3       ***
    1300.         3       ***
    1400.         2       **
    1500.         2       **

--
? NSCO C12 C22
--
? PLOT C12 C22
```



```
HIST GLUE STRENGTH FOR DEAD PINE (5+ YEARS) C13

    MIDDLE OF    NUMBER OF
    INTERVAL     OBSERVATIONS
       700.        1      *
       800.        0
       900.        0
      1000.        1      *
      1100.        2      **
      1200.        3      ***
      1300.        6      ******
      1400.        3      ***
      1500.        2      **

--
? NSCO C13 C23
--
? PLOT C13 C23
```

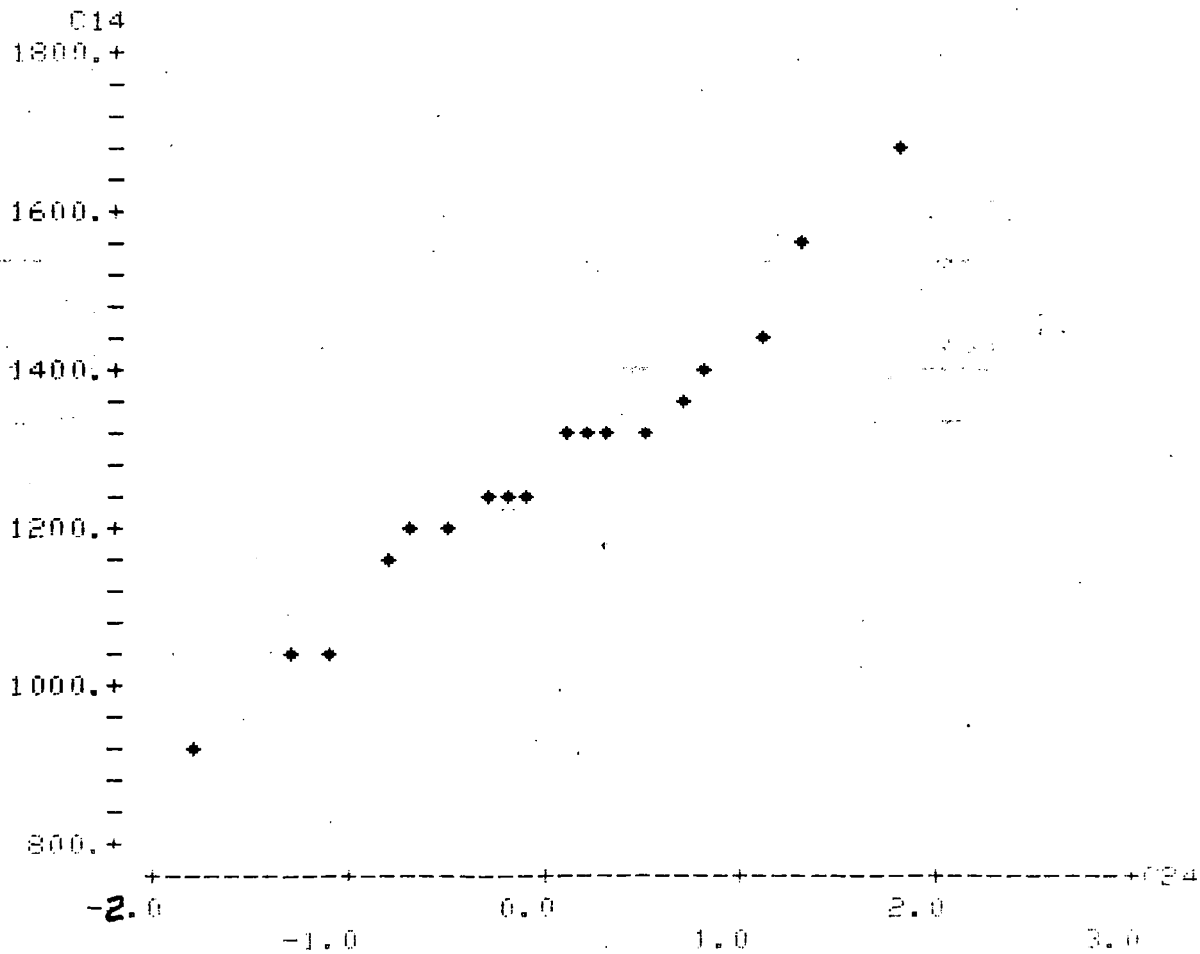


```
HIST LOG GLUE STRENGTH FOR/DEAD PINE (5+ YEARS) C13

    MIDDLE OF     NUMBER OF
    INTERVAL      OBSERVATIONS
       2.85          1      *
       2.90          0
       2.95          0
       3.00          1      *
       3.05          2      **
       3.10          8      ********
       3.15          5      *****
       3.20          1      *

--
? NSCO C13 C23
--
? PLOT C13 C23
```

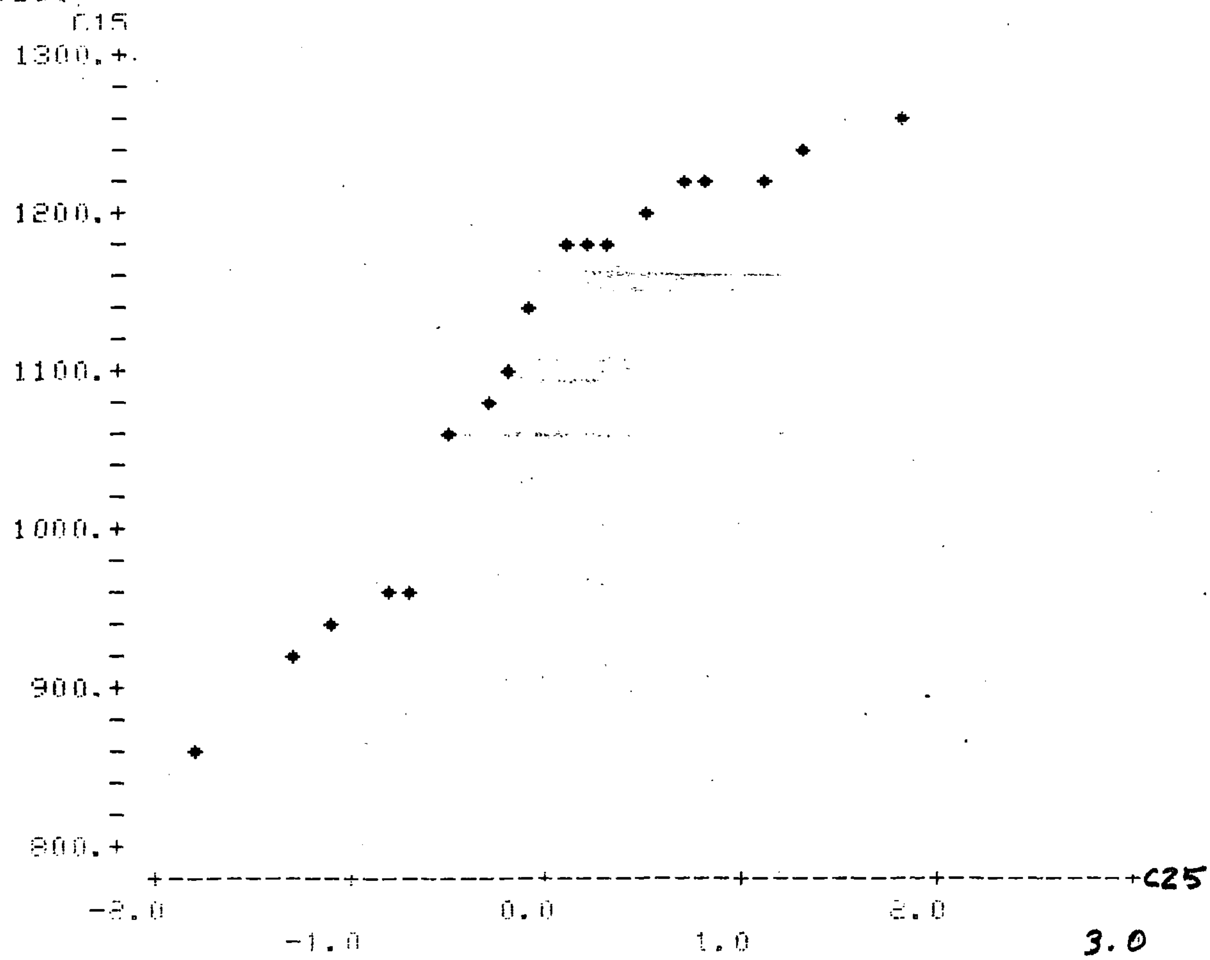


--

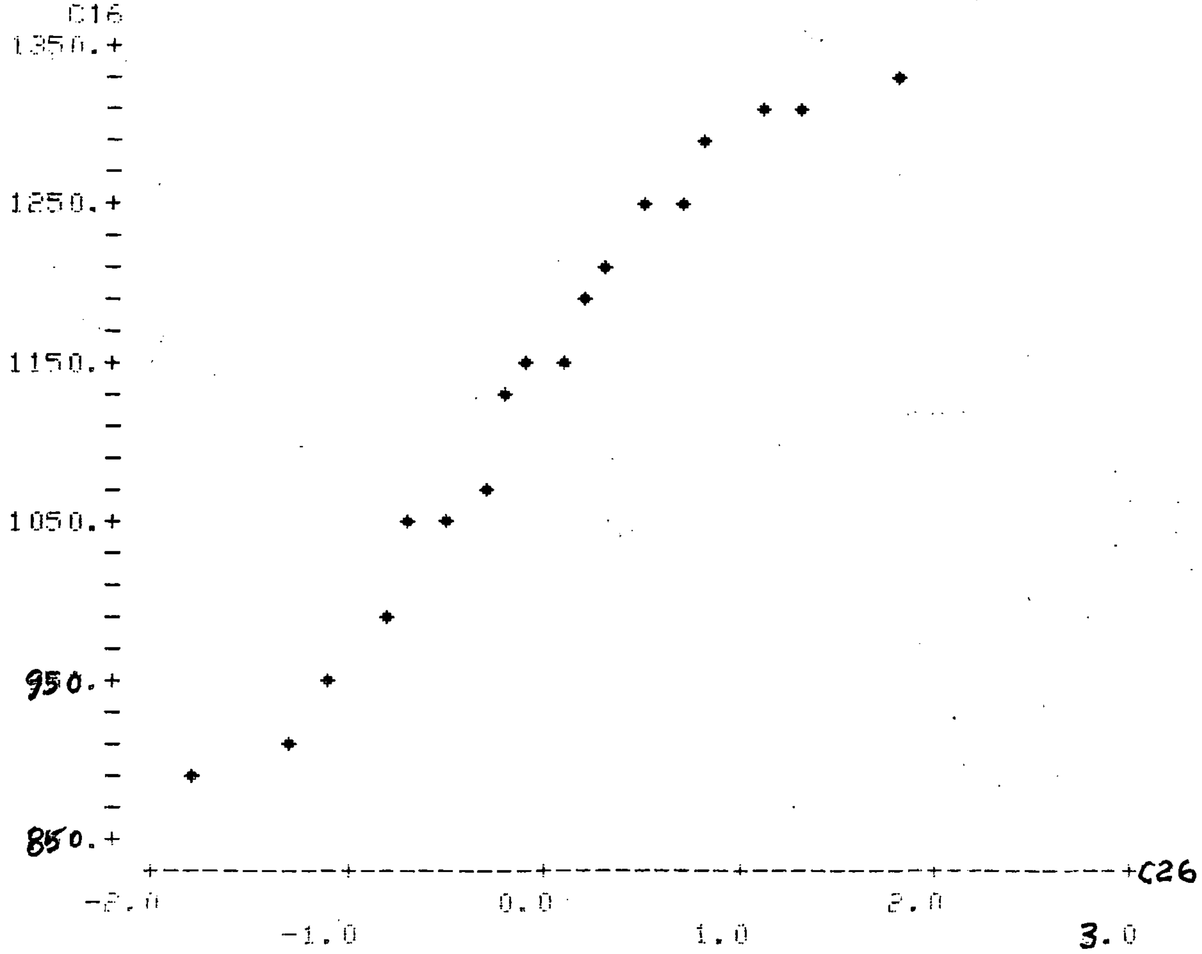
```
HIST GLUE STRENGTH FOR PINE THINNINGS C14

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
      900.        1      *
     1000.        2      **
     1100.        0
     1200.        5      *****
     1300.        6      ******
     1400.        2      **
     1500.        0
     1600.        1      *
     1700.        1      *

 --
? NSCO C14 C24
 --
? PLOT C14 C24
```



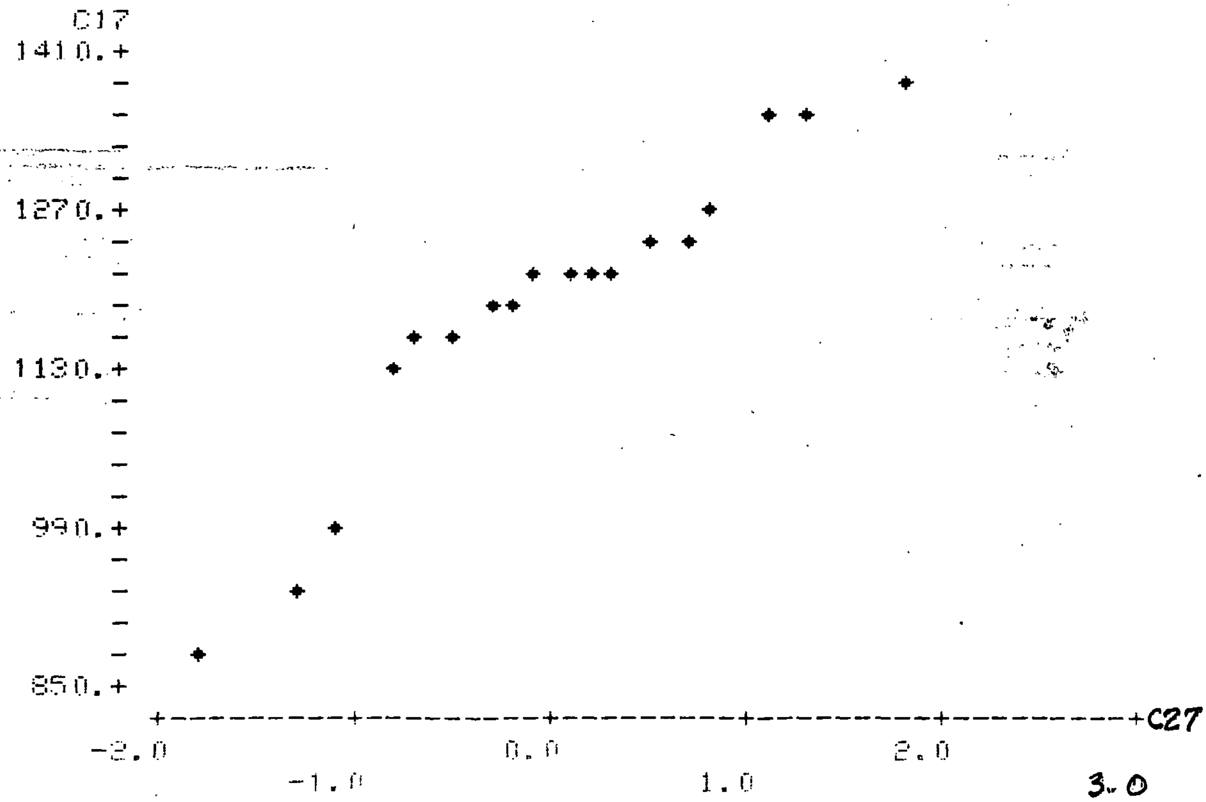
```
HIST GLUE STRENGTH FOR LIVE SPRUCE C15

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
      850.         1      *
      900.         1      *
      950.         3      ***
     1000.         0
     1050.         1      *
     1100.         2      **
     1150.         2      **
     1200.         6      ******
     1250.         2      **

--
? NSCO C15 C25
--
? PLOT C15 C25
```



```
HIST GLUE STRENGTH FOR DEAD SPRUCE C16

   MIDDLE OF    NUMBER OF
   INTERVAL     OBSERVATIONS
      900.         2      **
      950.         1      *
     1000.         1      *
     1050.         3      ***
     1100.         1      *
     1150.         2      **
     1200.         2      **
     1250.         2      **
     1300.         3      ***
     1350.         1      *

 --
? NSCO C16 C26
 --
? PLOT C16 C26
```

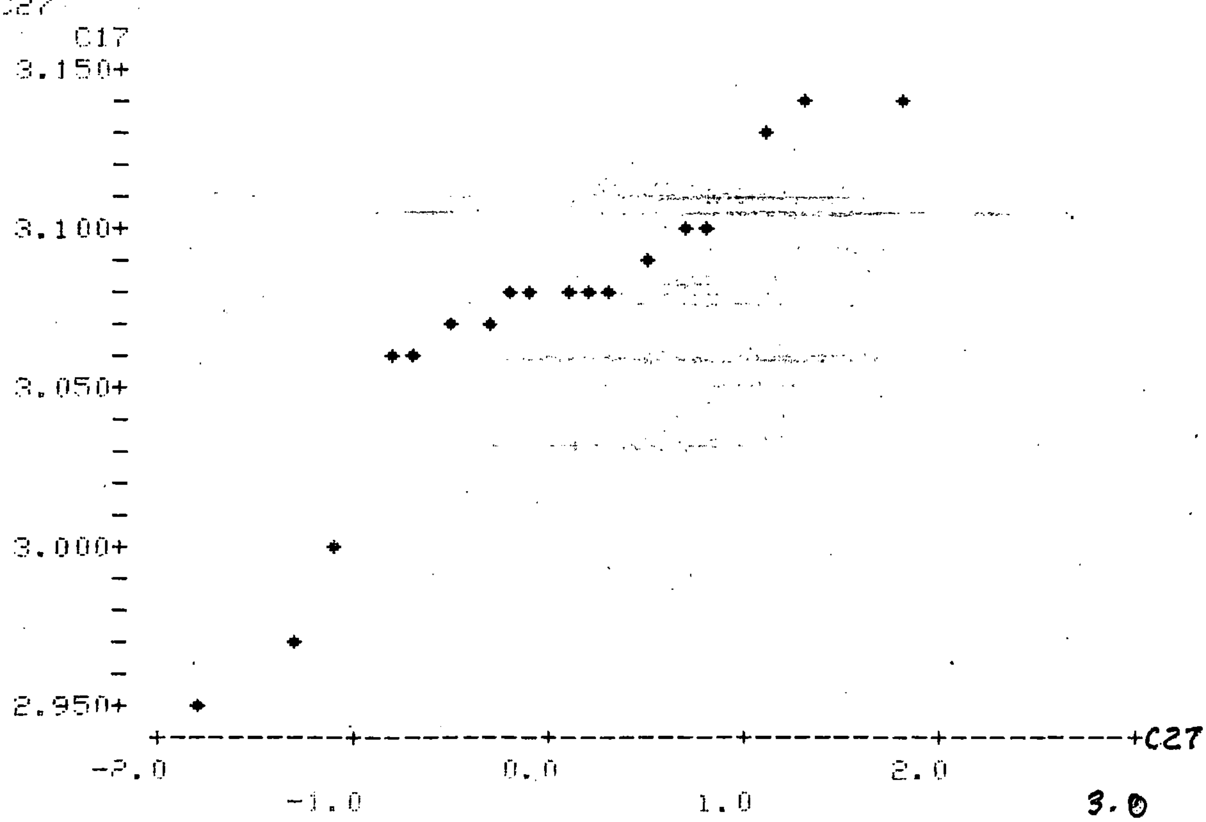


```
HIST GLUE STRENGTH FOR SPRUCE THINNINGS C17

  MIDDLE OF   NUMBER OF
  INTERVAL    OBSERVATIONS
     900.        2     **
     950.        0
    1000.        1     *
    1050.        0
    1100.        0
    1150.        3     ***
    1200.        6     ******
    1250.        3     ***
    1300.        0
    1350.        2     **
    1400.        1     *

--
? NSCO C17 C27
--
? PLOT C17 C27
```




```
--
?
```

```
HIST LOG GLUE STRENGTH FOR SPRUCE THINNINGS C17

  MIDDLE OF    NUMBER OF
  INTERVAL     OBSERVATIONS
     2.94         1     *
     2.96         1     *
     2.98         0
     3.00         1     *
     3.02         0
     3.04         0
     3.06         3     ***
     3.08         6     ******
     3.10         3     ***
     3.12         1     *
     3.14         2     **

--
? NSCO C17 C27
--
? PLOT C17 C27
```



--

APPENDIX D

GLUE SHEAR BLOCK TEST

ANALYSIS OF VARIANCE

ONEW MOISTURE CONTENT FOR GLUABILITY SPECIMENS (ALL DATA) C2 C1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	35.00	5.83	3.15
ERROR	119	220.38	1.85	
TOTAL	125	255.39		

LEVEL	N	MEAN	ST. DEV.
1	18	10.11	.78
2	18	9.94	.88
3	18	10.09	1.49
4	18	10.36	1.25
5	18	10.95	1.49
6	18	9.05	1.92
7	18	9.90	1.37

POOLED ST. DEV. = 1.36

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1                     I♦♦♦♦♦♦♦♦I♦♦♦♦♦♦♦♦I
2                   I♦♦♦♦♦♦♦♦I♦♦♦♦♦♦♦♦I
3                     I♦♦♦♦♦♦♦♦I♦♦♦♦♦♦♦♦I
4                         I♦♦♦♦♦♦♦♦I♦♦♦♦♦♦♦♦I
5                                 I♦♦♦♦♦♦♦♦I♦♦♦♦♦♦♦♦♦I
6      I♦♦♦♦♦♦♦♦I♦♦♦♦♦♦♦♦I
7                  I♦♦♦♦♦♦♦♦I♦♦♦♦♦♦♦♦♦I
       +---------+---------+---------+---------+---------+---------+
     8.40      9.10      9.80     10.50     11.20     11.90     12.60
```

--
?

LEVELS: 1 = LIVE LODGEPOLE, 2 = DEAD LODGEPOLE (5< YRS.), 3 = DEAD LODGEPOLE (5+ YRS.), 4 = LODGEPOLE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE-FIR THINNINGS

COLUMNS: 1 = 5 MINUTE ASSEMBLY TIME, 2 = 15 MINUTE ASSEMBLY TIME

TWOW GLUABILITY FOR ALL DATA C3 C1 C6

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF
C1	6	400762.	66794.
C6	1	3012.	3012.
C1 * C6	6	182208.	30368.
ERROR	112	2914402.	26021.
TOTAL	125	3500383.	

CELL MEANS
ROWS ARE LEVELS OF C1 COLS ARE LEVELS OF C6

	1	2	ROW MEANS
1	1259.	1147.	1203.
2	1192.	1184.	1188.
3	1279.	1230.	1254.
4	1311.	1243.	1277.
5	1047.	1161.	1104.
6	1093.	1180.	1136.
7	1201.	1169.	1185.
COL. MEANS	1197.	1188.	1193.

POOLED ST. DEV. = 161.

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS OF C1
(BASED ON POOLED STANDARD DEVIATION)

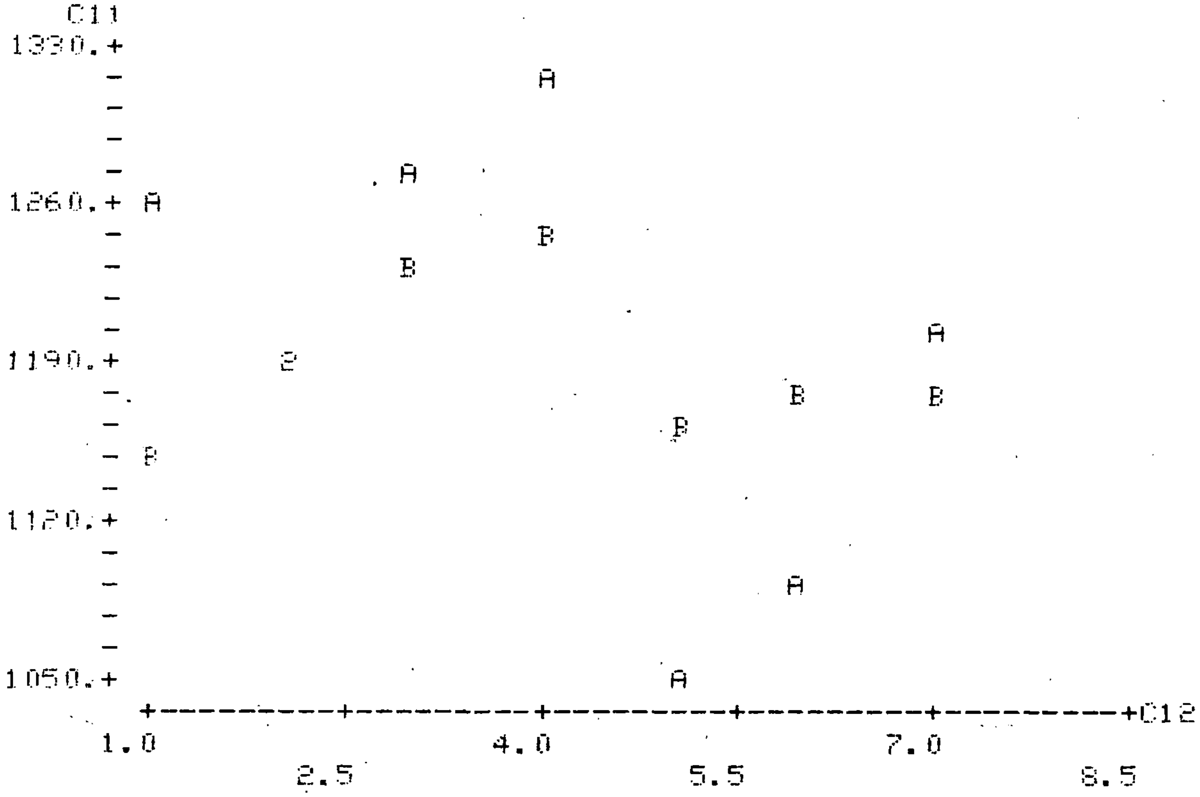
```
       +---------+---------+---------+---------+---------+---------+
1                          I*********I*********I
2                        I*********I*********I
3                                 I*********I*********I
4                                     I*********I*********I
5               I*********I*********I
6                    I*********I*********I
7                        I*********I*********I
       +---------+---------+---------+---------+---------+---------+
     980.     1050.     1120.     1190.     1260.     1330.     1400.
```

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS OF C6
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1                 I*****************I*****************I
2            I*****************I*****************I
       +---------+---------+---------+---------+---------+---------+
     1140.     1160.     1180.     1200.     1220.     1240.     1260.
```

--

LPLOT C11 C12 C13



C11 = AVERAGE GLUE LINE STRENGTH (PSI)
C12 = CATEGORIES (1=LIVE PINE, 2=DEAD PINE LESS THAN 5 YEARS, 3=DEAD PINE OVER 5 YEARS, 4=PINE THINNINGS, 5=LIVE SPRUCE, 6=DEAD SPRUCE, 7=SPRUCE THINNINGS)
C13 = CLOSED ASSEMBLY TIMES (1=5 MINUTES, 2=15 MINUTES)

APPENDIX E

NAIL WITHDRAWAL TEST

NAIL WITHDRAWAL TEST

COLUMN 1 = LINE NUMBERS

COLUMN 2 = MATERIAL CLASS (1 = LIVE LODGEPOLE, 2 = DEAD PINE <5 YRS., 3 = DEAD PINE 5+ YRS., 4 = PINE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE THINNINGS, 8 = FIR THINNINGS)

COLUMN 3 & 4 = NAIL WITHDRAWAL LOAD IN KG. FOR FACE

COLUMN 5 & 6 = NAIL WITHDRAWAL LOAD IN KG. FOR EDGE

00100	1	051	031	045	040
00110	1	138	071	071	093
00120	1	072	058	062	049
00130	1	049	040	055	057
00140	1	050	070	055	035
00150	1	064	065	059	062
00160	1	058	081	074	070
00170	1	042	064	067	072
00180	1	049	052	049	053
00190	1	096	102	104	099
00200	1	058	063	074	070
00201	1	056	042	043	053
00210	1	050	064	057	063
00220	1	068	049	050	057
00230	1	063	048	053	048
00240	1	061	062	075	054
00250	1	089	082	101	078
00260	1	096	100	101	100
00270	1	045	037	040	050
00280	1	076	075	063	067
00290	1	060	062	059	058
00300	2	065	060	059	046
00310	2	057	147	068	072
00320	2	050	045	045	042
00330	2	041	057	056	046
00340	2	066	064	039	040
00350	2	054	058	055	041
00360	2	062	056	081	065
00370	2	058	055	056	067
00380	2	106	096	101	072
00390	2	063	081	085	077
00400	2	066	070	059	059
00410	2	090	139	100	064
00420	2	068	051	056	057
00430	2	051	046	056	048
00440	2	000	051	042	049
00450	2	037	077	055	060
00460	2	065	058	063	064
00470	2	060	056	083	086
00480	2	046	055	036	048
00490	2	066	070	060	065
00500	3	100	086	104	089
00510	3	048	102	064	049
00520	3	064	053	067	068
00530	3	034	039	041	057
00540	3	052	054	075	055
00550	3	058	061	057	054
00560	3	053	049	058	079
00570	3	069	063	047	073
00580	3	098	089	082	070
00590	3	054	054	073	084
00600	3	080	042	066	112
00610	3	035	040	032	041
00620	3	068	048	054	053

00630	3	055	055	054	071
00640	3	097	089	101	093
00650	3	049	043	043	038
00660	3	054	051	074	067
00670	3	064	058	055	042
00680	3	045	037	041	039
00690	3	039	056	045	034
00700	4	113	120	093	117
00710	4	087	097	067	089
00720	4	080	105	099	108
00730	4	077	064	096	086
00740	4	067	070	056	051
00750	4	103	058	077	068
00760	4	099	103	131	136
00770	4	053	076	063	076
00780	4	075	091	071	085
00790	4	053	056	072	059
00800	4	049	075	073	091
00801	4	113	090	133	099
00802	4	087	080	089	090
00810	4	068	095	091	095
00820	4	074	051	079	078
00830	4	083	084	080	063
00840	4	070	060	070	082
00850	4	101	054	056	058
00860	4	082	080	119	102
00870	4	083	091	090	075
00880	5	060	058	054	061
00890	5	085	097	066	076
00900	5	062	058	050	036
00910	5	059	046	061	057
00920	5	066	067	070	063
00930	5	056	038	060	044
00940	5	034	036	062	060
00950	5	091	050	073	038
00960	5	050	050	039	056
00970	5	042	056	058	049
00980	5	067	064	073	074
00990	5	042	036	050	056
01000	5	054	054	060	056
01010	5	109	073	079	070
01020	5	060	042	049	040
01030	5	140	062	160	053
01040	5	096	049	104	041

01050	5	061	062	058	058
01060	5	048	050	052	052
01070	5	055	041	056	049
01080	6	098	058	057	095
01090	6	046	036	046	040
01100	6	046	050	052	044
01110	6	048	040	031	044
01120	6	048	033	032	050
01130	6	051	056	050	053
01140	6	100	092	087	100
01150	6	054	051	059	064
01160	6	065	057	064	063
01170	6	050	040	052	053
01180	6	073	063	069	054
01190	6	082	083	104	060
01200	6	038	031	048	052
01210	6	060	049	049	047
01220	6	058	066	056	054
01230	6	068	038	068	040
01240	6	070	103	050	088
01250	6	058	055	055	058
01260	6	041	050	040	048
01270	6	036	040	041	048
01280	7	089	086	091	081
01290	7	107	083	075	074
01300	7	110	060	087	072
01310	8	057	042	049	056
01320	7	104	092	121	095
01330	7	074	085	076	096
01340	8	054	053	065	064
01350	7	070	067	079	080
01360	7	107	085	084	083
01370	7	065	057	066	060
01380	7	069	084	077	044
01390	8	052	049	070	092
01400	7	076	080	071	080
01410	7	075	074	073	080
01420	7	069	061	062	070
01430	7	086	063	056	060
01440	8	086	063	056	060
01450	7	067	064	070	064
01460	7	061	072	096	060
01470	7	076	104	072	090

APPENDIX E

NAIL WITHDRAWAL TEST

TEST FOR NORMALITY

HISTOGRAMS

```
MIDDLE OF     NUMBER OF
INTERVAL      OBSERVATIONS
    40.          1      *
    45.          1      *
    50.          3      ***
    55.          3      ***
    60.          4      ****
    65.          3      ***
    70.          2      **
    75.          0
    80.          0
    85.          0
    90.          1      *
    95.          1      *
   100.          2      **
```

--

? HIST NAIL WITHDRAWAL FOR DEAD PINE (LESS THAN 5 YEARS) C22

```
MIDDLE OF     NUMBER OF
INTERVAL      OBSERVATIONS
    40.          1      *
    50.          6      ******
    60.          6      ******
    70.          3      ***
    80.          1      *
    90.          2      **
   100.          1      *
```

--

? HIST NAIL WITHDRAWAL FOR DEAD PINE (OVER 5 YEARS) C23

```
MIDDLE OF     NUMBER OF
INTERVAL      OBSERVATIONS
    35.          1      *
    40.          1      *
    45.          3      ***
    50.          0
    55.          2      **
    60.          5      *****
    65.          4      ****
    70.          0
    75.          1      *
    80.          0
    85.          1      *
    90.          0
    95.          2      **
```

--

? HIST NAIL WITHDRAWAL FOR PINE THINNINGS C24

```
MIDDLE OF     NUMBER OF
INTERVAL      OBSERVATIONS
    60.          2      **
    65.          2      **
    70.          3      ***
    75.          1      *
    80.          3      ***
    85.          4      ****
    90.          0
    95.          1      *
   100.          1      *
   105.          0
   110.          2      **
   11[illegible] [illegible]
```

HIST NAIL WITHDRAWAL FOR LIVE SPRUCE C25

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
45.	1	*
50.	8	********
55.	2	**
60.	2	**
65.	2	**
70.	1	*
75.	1	*
80.	1	*
85.	1	*
90.	0	
95.	0	
100.	0	
105.	1	*

--

? HIST NAIL WITHDRAWAL FOR DEAD SPRUCE (DEAD 20 25 YEARS) C26

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
40.	5	*****
45.	1	*
50.	3	***
55.	4	****
60.	2	**
65.	1	*
70.	0	
75.	1	*
80.	2	**
85.	0	
90.	0	
95.	1	*

--

? HIST NAIL WITHDRAWAL FOR SPRUCE=FIR THINNINGS C27

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
50.	1	*
55.	0	
60.	2	**
65.	5	*****
70.	2	**
75.	3	***
80.	1	*
85.	4	****
90.	1	*
95.	0	
100.	0	
105.	1	*

HIST NAIL TEST NATURAL LOG TRANSFERED FOR LIVE PINE C21

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
3.7	1	*
3.8	1	*
3.9	3	***
4.0	3	***
4.1	6	******
4.2	1	*
4.3	2	**
4.4	0	
4.5	2	**
4.6	2	**

--

? HIST NAIL TEST NATURAL LOG TRANSFERED FOR DEAD PINE (DEAD LESS THAN 5 YEARS) C22

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
3.6	1	*
3.7	0	
3.8	2	**
3.9	2	**
4.0	3	***
4.1	4	****
4.2	3	***
4.3	2	**
4.4	0	
4.5	2	**
4.6	1	*

--

? HIST NAIL TEST LOG TRANSFERED FOR DEAD PINE (DEAD OVER 5 YEARS) C23

MIDDLE OF INTERVAL	NUMBER OF OBSERVATIONS	
3.6	1	*
3.7	1	*
3.8	3	***
3.9	0	
4.0	2	**
4.1	7	*******
4.2	2	**
4.3	1	*
4.4	1	*
4.5	0	
4.6	2	**

--

?

APPENDIX E

NAIL WITHDRAWAL TEST

ANALYSIS OF VARIANCE

ONEW FOR %MC FOR NAIL TEST C11 C31

```
                          LEVEL
               ALL
               DATA    1      2      30     40     50     60     70

          -       1                                         1
          -       1                  1
          -
   12.0   +
          -       1                                  1
          -       1                  1
          -       6                         1        3             2
          -      13    3                    2        2      3      3
   10.0   +      25    4             2      7        2      5      5
          -      30    4      1      1      5        9      4      6
          -      22    5      2      1      4        1      6      3
          -       9    3      3      1                      1      1
          -       6    1      3      2
```

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	10.280	1.713	3.37
ERROR	108	54.859	.508	
TOTAL	114	65.138		

LEVEL	N	MEAN	ST. DEV.
1	20	9.507	.557
2	9	8.870	.412
30	9	9.831	1.431
40	19	9.809	.457
50	18	10.051	.629
60	20	9.859	.913
70	20	9.836	.509

POOLED ST. DEV. = .713

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
1                         I*******I*******I
2     I***********I***********I
30                            I***********I***********I
40                               I*******I*******I
50                                     I*******I********I
60                                 I******I*******I
70                                I*******I*******I
      +---------+---------+---------+---------+---------+---------
    8.40      8.80      9.20      9.60     10.00     10.40     10.80
```

LEVELS: 1 = LIVE LODGEPOLE, 2 = DEAD PINE LESS 5 YRS., 3 = DEAD PINE 5+ YRS., 4 = PINE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE THINNINGS, 8 = FIR THINNINGS

ONEW LOG NAIL TEST FOR ALL DATA WITH FIR THINNINGS SEPARATED C7 C1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	7	2.5053	.3579	6.78
ERROR	133	7.0181	.0528	
TOTAL	140	9.5234		

LEVEL	N	MEAN	ST. DEV.
1	21	4.131	.253
2	20	4.102	.252
3	20	4.079	.265
4	20	4.400	.192
5	20	4.080	.222
6	20	4.008	.254
7	16	4.343	.139
8	4	4.097	.122

POOLED ST. DEV. = .230

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+---------+
1                  I******I*****I
2                I******I*******I
3              I******I*******I
4                                     I******I*****I
5               I*****I*******I
6           I******I*****I
7                                 I*******I******I
8        I**************I***************I
       +---------+---------+---------+---------+---------+---------+---------+
     3.85      4.00      4.15      4.30      4.45      4.60      4.75
```

ONEW LOG NAIL TEST FOR PINE DATA C11 C10

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	1.3434	.4478	7.62
ERROR	77	4.5239	.0588	
TOTAL	80	5.8673		

LEVEL	N	MEAN	ST. DEV.
1	21	4.131	.253
2	20	4.102	.252
3	20	4.079	.265
4	20	4.400	.192

POOLED ST. DEV. = .242

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
         +---------+---------+---------+---------+---------+---------+
1                       I**********I***********I
2                   I***********I***********I
3                 I***********I***********I
4                                                  I***********I***********I
         +---------+---------+---------+---------+---------+---------+
       3.95      4.05      4.15      4.25      4.35      4.45      4.55
```

--

ONEW LOG NAIL TEST FOR PINE DATA WITH THINNINGS REMOVED C21 C20

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	.0279	.0140	.21
ERROR	58	3.8257	.0660	
TOTAL	60	3.8536		

LEVEL	N	MEAN	ST. DEV.
1	21	4.131	.253
2	20	4.102	.252
3	20	4.079	.265

POOLED ST. DEV. = .257

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
         +---------+---------+---------+---------+---------+---------+
1                     I******************I******************I
2                 I******************I******************I
3            I******************I******************I
         +---------+---------+---------+---------+---------+---------+
       3.960     4.020     4.080     4.140     4.200     4.260     4.320
```

--

```
ONEW LOG NAIL TEST FOR SPRUCE-FIR DATA WITH FIR THINNINGS SEPARATED C12

ANALYSIS OF VARIANCE

DUE TO          DF          SS       MS=SS/DF      F-RATIO
FACTOR           3      1.0755         .3585         8.05
ERROR           56      2.4943         .0445
TOTAL           59      3.5697

LEVEL          N            MEAN        ST. DEV.
5             20           4.080          .222
6             20           4.008          .254
7             16           4.343          .139
8              4           4.097          .122

POOLED ST. DEV. =           .211

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
5                   I*********I********I
6            I*********I********I
7                                                I*********I**********I
8          I********************I********************I
       +---------+---------+---------+---------+---------+---------+
     3.85      3.95      4.05      4.15      4.25      4.35      4.45

--
```

```
ONEW LOG NAIL TEST FOR SPRUCE DATA WITH THINNINGS REMOVED C22 C23

ANALYSIS OF VARIANCE

DUE TO          DF          SS       MS=SS/DF      F-RATIO
FACTOR           1       .0513         .0513          .90
ERROR           38      2.1594         .0568
TOTAL           39      2.2106

LEVEL          N            MEAN        ST. DEV.
5             20           4.080          .222
6             20           4.008          .254

POOLED ST. DEV. =           .238

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
5                  I*****************I*****************I
6      I*****************I*****************I
       +---------+---------+---------+---------+---------+---------+
     3.900     3.980     4.020     4.080     4.140     4.200     4.260

--
?
```

APPENDIX F

TREATABILITY TEST

TREATABILITY TEST

COLUMN 1 = RETENTION IN POUNDS PER CUBIC INCH
COLUMN 2 = PERCENT SAPWOOD
COLUMN 3 = MATERIAL CLASS (1 = LIVE LODGEPOLE, 2 = DEAD LODGEPOLE <5 YRS., 3 = DEAD PINE 5+ YRS, 4 = LODGEPOLE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE-FIR THINNINGS)
COLUMN 4 = TREATMENT TIME (1 = 12 HOURS, 2 = 24 HOURS, 3 = 36 HOURS)

.4	0	1	1
.5	0	1	2
.7	0	1	3
.3	22	1	1
.3	22	1	2
.4	22	1	3
1.0	95	1	1
1.1	95	1	2
1.3	95	1	3
.2	0	1	1
.3	0	1	2
.4	0	1	3
.6	67	1	1
.8	67	1	2
.8	67	1	3
.9	83	1	1
1.0	83	1	2
1.1	83	1	3
.3	17	1	1
.3	17	1	2
.4	17	1	3
.1	0	1	1
.2	0	1	2
.2	0	1	3
.5	9	1	1
.6	9	1	2
.6	9	1	3
.2	0	1	1
.3	0	1	2
.3	0	1	3
.3	0	1	1
.3	0	1	2
.4	0	1	3
.9	100	1	1
1.0	100	1	2
1.1	100	1	3
.3	30	1	1
.3	30	1	2
.3	30	1	3
.4	0	1	1
.5	0	1	2
.6	0	1	3
.1	0	1	1
.2	0	1	2
.2	0	1	3
.3	15	1	1
.4	15	1	2
.5	15	1	3
.3	14	1	1
.3	14	1	2
.3	14	1	3

.2	0	1	1
.2	0	1	2
.2	0	1	3
.1	0	1	1
.1	0	1	2
.1	0	1	3
.3	22	1	1
.4	22	1	2
.4	22	1	3
.1	3	2	1
.1	3	2	2
.2	3	2	3
.8	41	2	1
.9	41	2	2
.9	41	2	3
.2	35	2	1
.3	35	2	2
.4	35	2	3
.3	30	2	1
.3	30	2	2
.4	30	2	3
.5	88	2	1
.6	88	2	2
.7	88	2	3
1.1	82	2	1
1.2	82	2	2
1.4	82	2	3
.8	54	2	1
.8	54	2	2
.9	54	2	3
.4	8	2	1
.5	8	2	2
.6	8	2	3
1.2	72	2	1
1.4	72	2	2
1.7	72	2	3
.8	0	2	1
1.1	0	2	2
1.2	0	2	3
.1	0	2	1
.1	0	2	2
.2	0	2	3
2.0	100	2	1
2.3	100	2	2
2.4	100	2	3
.9	86	2	1
1.0	86	2	2
1.1	86	2	3
.9	72	2	1
1.0	72	2	2
1.1	72	2	3

.2	0	2	1
.2	0	2	2
.3	0	2	3
.6	52	2	1
.7	52	2	2
.8	52	2	3
.4	58	2	1
.5	58	2	2
.6	58	2	3
.5	31	2	1
.6	31	2	2
.6	31	2	3
.2	31	2	1
.3	31	2	2
.3	31	2	3
.1	0	2	1
.2	0	2	2
.2	0	2	3
.4	11	3	1
.4	11	3	2
.4	11	3	3
.4	5	3	1
.5	5	3	2
.5	5	3	3
.1	0	3	1
.2	0	3	2
.2	0	3	3
.2	0	3	1
.3	0	3	2
.3	0	3	3
.2	0	3	1
.3	0	3	2
.4	0	3	3
.2	0	3	1
.3	0	3	2
.3	0	3	3
.3	0	3	1
.3	0	3	2
.4	0	3	3
.3	0	3	1
.3	0	3	2
.4	0	3	3
1.2	0	3	1
1.3	0	3	2
1.4	0	3	3
.3	6	3	1
.3	6	3	2
.3	6	3	3
.2	0	3	1
.3	0	3	2
.3	0	3	3

.4	11	3	1
.5	11	3	2
.6	11	3	3
.2	0	3	1
.3	0	3	2
.3	0	3	3
.1	0	3	1
.1	0	3	2
.2	0	3	3
.7	42	3	1
.7	42	3	2
.7	42	3	3
1.4	38	3	1
1.5	38	3	2
1.6	38	3	3
1.5	65	3	1
1.6	65	3	2
1.7	65	3	3
.2	0	3	1
.3	0	3	2
.3	0	3	3
.2	0	3	1
.3	0	3	2
.4	0	3	3
.1	0	3	1
.2	0	3	2
.2	0	3	3
.6	67	4	1
.7	67	4	2
.8	67	4	3
.6	38	4	1
.7	38	4	2
.7	38	4	3
.4	37	4	1
.4	37	4	2
.5	37	4	3
.6	76	4	1
.7	76	4	2
.7	76	4	3
.7	91	4	1
.8	91	4	2
.9	91	4	3
.3	9	4	1
.4	9	4	2
.4	9	4	3
.4	45	4	1
.5	45	4	2
.5	45	4	3
.6	81	4	1
.7	81	4	2
.8	81	4	3
.4	38	4	1
.5	38	4	2
.5	38	4	3
.1	7	4	1
.2	7	4	2
.2	7	4	3
1.7	63	4	1
1.9	63	4	2
1.9	63	4	3
.3	14	4	1
.3	14	4	2
.4	14	4	3
.4	32	4	1
.5	32	4	2
.5	32	4	3

.3	21	4	1
.4	21	4	2
.4	21	4	3
.4	9	4	1
.5	9	4	2
.5	9	4	3
.5	98	4	1
.7	98	4	2
.8	98	4	3
.3	51	4	1
.5	51	4	2
.5	51	4	3
.3	33	4	1
.4	33	4	2
.4	33	4	3
.7	67	4	1
.8	67	4	2
.8	67	4	3
.3	45	4	1
.4	45	4	2
.4	45	4	3
.8	92	5	1
.8	92	5	2
.9	92	5	3
.2	98	5	1
.2	98	5	2
.3	98	5	3
.2	100	5	1
.3	100	5	2
.3	100	5	3
.2	100	5	1
.3	100	5	2
.3	100	5	3
.2	100	5	1
.2	100	5	2
.3	100	5	3
.9	29	5	1
.9	29	5	2
1.0	29	5	3
.3	100	5	1
.3	100	5	2
.3	100	5	3
.9	85	5	1
1.0	85	5	2
1.0	85	5	3
.1	100	5	1
.2	100	5	2
.2	100	5	3
.6	91	5	1
.7	91	5	2
.7	91	5	3
.1	4	5	1
.1	4	5	2
.1	4	5	3
.2	100	5	1
.3	100	5	2
.4	100	5	3
2.0	79	5	1
2.3	79	5	2
2.6	79	5	3
.2	100	5	1
.3	100	5	2
.3	100	5	3
.4	100	5	1
.4	100	5	2
.5	100	5	3

.2	100	5	1
.3	100	5	2
.4	100	5	3
2.6	89	5	1
2.7	89	5	2
2.8	89	5	3
.2	0	5	1
.2	0	5	2
.2	0	5	3
3.0	39	5	1
3.2	39	5	2
3.4	39	5	3
.3	100	5	1
.3	100	5	2
.4	100	5	3
.2	100	6	1
.2	100	6	2
.3	100	6	3
.1	100	6	1
.1	100	6	2
.2	100	6	3
.2	100	6	1
.2	100	6	2
.3	100	6	3
.2	100	6	1
.2	100	6	2
.3	100	6	3
.2	100	6	1
.2	100	6	2
.3	100	6	3
.2	100	6	1
.2	100	6	2
.2	100	6	3
.2	0	6	1
.2	0	6	2
.2	0	6	3
.1	0	6	1
.1	0	6	2
.1	0	6	3
.1	100	6	1
.2	100	6	2
.2	100	6	3
.2	100	6	1
.2	100	6	2
.2	100	6	3
.1	0	6	1
.1	0	6	2
.2	0	6	3
.2	100	6	1
.2	100	6	2
.2	100	6	3
.2	0	6	1
.2	0	6	2
.2	0	6	3
.2	100	6	1
.2	100	6	2
.2	100	6	3
.1	74	6	1
.2	74	6	2
.2	74	6	3
.2	100	6	1
.3	100	6	2
.3	100	6	3
.2	100	6	1
.2	100	6	2
.2	100	6	3

.3	100	6	1
.4	100	6	2
.4	100	6	3
.2	100	6	1
.3	100	6	2
.3	100	6	3
.1	38	6	1
.2	38	6	2
.2	38	6	3
.1	41	7	1
.2	41	7	2
.2	41	7	3
.1	14	7	1
.2	14	7	2
.2	14	7	3
.1	71	7	1
.2	71	7	2
.2	71	7	3
.3	20	7	1
.4	20	7	2
.4	20	7	3
.1	15	7	1
.2	15	7	2
.2	15	7	3
.1	95	7	1
.2	95	7	2
.2	95	7	3
.2	53	7	1
.3	53	7	2
.3	53	7	3
.1	2	7	1
.1	2	7	2
.2	2	7	3
.2	56	7	1
.2	56	7	2
.2	56	7	3
.2	87	7	1
.2	87	7	2
.2	87	7	3
.1	21	7	1
.2	21	7	2
.2	21	7	3
.1	17	7	1
.2	17	7	2
.2	17	7	3
.1	5	7	1
.1	5	7	2
.1	5	7	3
.1	28	7	1
.1	28	7	2
.1	28	7	3
.1	24	7	1
.2	24	7	2
.2	24	7	3
.2	34	7	1
.2	34	7	2
.3	34	7	3
.1	70	7	1
.1	70	7	2
.2	70	7	3
.1	86	7	1
.2	86	7	2
.2	86	7	3
.1	2	7	1
.2	2	7	2
.2	2	7	3

ANALYSIS OF VARIANCE FOR 1-ST DEPENDENT VARIABLE

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	11.79394	1	11.79394	19.80625	.000
categories	19.58265	6	3.26377	5.48105	.000
1-ST COVAR	6.73307	1	6.73307	11.30724	.001
ERROR	78.60143	132	.59547		
R times 1,2,4,36	1.05729	2	.52864	211.77560	.000
RC	.13205	12	.01100	4.40822	.000 F
ERROR	.66400	266	.00250		

POOLED REGRESSION COEFFICIENTS

1-ST COVARIATE .00408

APPENDIX G

SPECIFIC GRAVITY

STRAIGHTNESS OF GRAIN

APPEARANCE TEST

VOLUMETRIC SHRINKAGE

FREEDOM FROM CHECKS

FREEDOM FROM WARP

LEVELS: 1 = LIVE LODGEPOLE, 2 = DEAD PINE LESS THAN 5 YRS., 3 = DEAD PINE 5+ YRS., 4 = PINE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE THINNINGS, 8 = FIR THINNINGS

```
ONEW SPECIFIC GRAVITY FOR PINE (CLL) C3 C4

                            LEVEL
              ALL
              DATA    1       2       3       4

          -     1                     1
    .480  +     2                             2
          -     1                             1
          -     4                             4
          -     4             2               2
          -    14     3       3       3       5
    .400  +    15     3       2       5       5
          -    25     3       9      10       3
          -    21     5       5       6       5
          -    11             5       3       3
          -     6             3       2       1

ANALYSIS OF VARIANCE

DUE TO        DF         SS       MS=SS/DF      F-RATIO
FACTOR         3    .011805      .003935         4.06
ERROR        100    .096945      .000969
TOTAL        103    .108750


LEVEL        N          MEAN        ST. DEV.
1           14         .3868         .0197
2           29         .3787         .0275
3           30         .3832         .0308
4           31         .4047         .0379

POOLED ST. DEV. =        .0311

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+---------+---------+---------+
1               I***************I**************I
2            I***********I***********I
3                 I**********I**********I
4                                     I**********I**********I
      +---------+---------+---------+---------+---------+---------+
    .360      .370      .380      .390      .400      .410      .420
```

DNEW SPECIFIC GRAVITY FOR SPRUCE C3 C4

```
                         LEVEL
            ALL
            DATA     5      6      7

         -     1                   1
         -     1                   1
         -     2                   2
         -     1     1
  .400   +     2                   2
         -     5                   5
         -     6            1      5
         -     5     1      1      3
         -     7     3      1      3
  .320   +    13     6      5      2
         -    31    13     12      6
         -    14     6      8
```

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	.05212	.02606	24.68
ERROR	85	.08976	.00106	
TOTAL	87	.14188		

LEVEL	N	MEAN	ST. DEV.
5	30	.3127	.0260
6	28	.3067	.0196
7	30	.3609	.0454

POOLED ST. DEV. = .0325

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
5           I*******I*******I
6        I*******I*******I
7                                         I*******I*******I
      +---------+---------+---------+---------+---------+---------+
    .290      .305      .320      .335      .350      .365      .380
```

ONEW SPECIFIC GRAVITY FOR ALL DATA (CLL) C1 C2

	ALL DATA	LEVEL 1	2	3	4	5	6	7
.50 +	1			1				
-	2				2			
-	3				2			1
-	7		1		4			2
-	16	3	3	3	5	1		1
.40 +	22	3	4	6	6			3
-	37	4	11	11	6			5
-	25	4	4	6	5		1	5
-	20		5	3	1	4	2	5
-	14		1			6	5	2
.30 +	37					17	14	6
-	8					2	6	

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	.24488	.04081	40.44
ERROR	185	.18670	.00101	
TOTAL	191	.43159		

LEVEL	N	MEAN	ST. DEV.
1	14	.3868	.0197
2	29	.3787	.0275
3	30	.3832	.0308
4	31	.4047	.0379
5	30	.3127	.0260
6	28	.3067	.0196
7	30	.3609	.0454

POOLED ST. DEV. = .0318

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
1                                   I******I*****I
2                                  I***I****I
3                                    I***I****I
4                                            I****I***I
5        I***I****I
6     I****I***I
7                            I***I****I
      +---------+---------+---------+---------+---------+---------+
    .295      .320      .345      .370      .395      .420      .445
```

GRAIN ANGLE EVALUATION

COLUMN 1 = MATERIAL CLASS (1 = LIVE LODGEPOLE, 2 = DEAD PINE <5 YRS., 3 = DEAD PINE 5+ YRS., 4 = PINE THINNINGS, 5 = LIVE SPRUCE, 6 = DEAD SPRUCE, 7 = SPRUCE-FIR THINNINGS)

COLUMN 2 = HORIZONTAL DISTANCE REQUIRED TO OBTAIN A 1-INCH RISE IN THE SLOPE OF THE GRAIN (00 = A PIECE WITH A HORIZONTAL DISTANCE GREATER THAN 29 INCHES WHICH WAS CONSIDERED AN ARBITRARY STRAIGHT PIECE)

1	14
1	00
1	24
1	25
1	00
1	00
1	21
1	27
1	14.5
1	00
1	00
1	00
1	00
1	00
2	10.3
2	25
2	00
2	9.1
2	13
2	14
2	16.5
2	00
2	00
2	11.5
2	22
2	16.9
2	10.8
2	09
2	00
2	00
2	00
2	13.1
2	00
2	00
2	00
2	00
2	00
2	00
2	00
2	00
2	15.4
2	00
2	00
3	13.3
3	09.2
3	20.5
3	25
3	08.6
3	00
3	15
3	12
3	27
3	00
3	10.5
3	00
3	00
3	00
3	28
3	00
3	13
3	23
3	20
3	00
3	00
3	24
3	21
3	00
3	10
3	00
3	17
3	15
3	00
3	09.8
4	00
4	15.6
4	00
4	15.6
4	00
4	26
4	00
4	00
4	00
4	19
4	00
4	19.1
4	00
4	15.1
4	00
4	00
4	28
4	00
4	00
4	00
4	00
4	00
4	00
4	00
4	00
4	00
4	21
4	21
4	00
4	00
4	00
5	00
5	00
5	00
5	00
5	21
5	00
5	00
5	00
5	00
5	00
5	00
5	26
5	12
5	00
5	12
5	22
5	00
5	00
5	00
5	00
5	00
5	00
5	00
5	00
5	15
5	00
5	25
5	29
5	21
5	18
6	08.3
6	00
6	00
6	00
6	23
6	18.2
6	21
6	21
6	09.2
6	18
6	24
6	10.8
6	29
6	00
6	29
6	00
6	00
6	00
6	00
6	00
6	20
6	00
6	00
6	17
6	00
6	00
6	16
6	00
6	00
8	09.8
8	00
6	16
7	17
7	14.7
7	12.1
7	00
7	10.9
7	12.5
7	00
7	00
8	00
7	00
7	27
7	00
7	00
7	00
7	22
7	00
7	16
7	00
7	18
7	16
7	00
7	00
7	00
7	00
7	00
7	00
7	00
7	17.3

STRAIGHTNESS OF GRAIN = THE HORIZONTAL DISTANCE REQUIRED TO OBTAIN A 1 INCH RISE MULTIPLIED BY 3.44828 (ANY VALUE FOR HORIZONTAL DISTANCE 29 OR GREATER IS CONSIDERED TO BE PERFECTLY STRAIGHT AND IS GIVEN A VALUE OF 100

ONEW STRAIGHTNESS OF GRAIN FOR ALL DATA WITH SPRUCE AND FIR SEPARATED C4 C1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	7	7654.	1093.	2.00
ERROR	186	101520.	546.	
TOTAL	193	109174.		

LEVEL	N	MEAN	ST. DEV.
1	14	87.9	18.9
2	29	76.9	23.3
3	30	73.3	27.3
4	31	90.9	16.8
5	30	89.8	18.5
6	30	88.1	23.8
7	27	82.4	24.0
8	3	77.0	39.8

POOLED ST. DEV. = 23.4

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
1.                              I***********I***********I
2.                      I*******I*******I
3.                   I*******I*******I
4.                                     I*******I*******I
5.                                   I*******I*******I
6.                             I*******I*******I
7.                             I*******I********I
8.    I**************************I************************I
      +---------+---------+---------+---------+---------+---------+
     50.       60.       70.       80.       90.      100.      110.
```

ONEW STRAIGHTNESS OF GRAIN FOR PINE C14 C11

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	5912.	1971.	3.46
ERROR	100	57012.	570.	
TOTAL	103	62923.		

LEVEL	N	MEAN	ST. DEV.
1	14	87.9	18.8
2	29	76.9	28.3
3	30	73.3	27.3
4	31	90.9	16.8

POOLED ST. DEV. = 23.9

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
1                          I***************I***************I
2             I**********I***********I
3         I**********I**********I
4                                   I**********I*********I
      +---------+---------+---------+---------+---------+---------+
    64.0      72.0      80.0      88.0      96.0     104.0     112.0
```

ONEW STRAIGHTNESS OF GRAIN FOR SPRUCE-FIR WITH FIR SEPARATED C24 C21

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	1300.	433.	.84
ERROR	86	44508.	518.	
TOTAL	89	45808.		

LEVEL	N	MEAN	ST. DEV.
5	30	89.8	18.5
6	30	82.1	23.8
7	27	82.4	24.0
8	3	77.0	39.8

POOLED ST. DEV. = 22.7

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
      +---------+---------+---------+---------+---------+---------+
5                                        I*******I*******I
6                                I*******I*******I
7                                I*******I********I
8      I*************************I*************************I
      +---------+---------+---------+---------+---------+---------+
     50.       60.       70.       80.       90.      100.      110.
```

```
ONEW APPEARANCE FOR ALL DATA C6 C1

                           LEVEL
                ALL
                DATA   1     2     3     4     5     6     7

             -    44   7     9     5     5     9     5     4
             -
        200. +
             -    81   6    13    17     9    13    16     7
             -
             -    32   2     5     2     7     2     8     6
             -
        100. +
             -
             -
             -
             -    15         1           6     3     1     4
```

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	54136.	9023.	2.84
ERROR	165	523881.	3175.	
TOTAL	171	578017.		

LEVEL	N	MEAN	ST. DEV.
1	15	196.5	36.4
2	28	180.5	47.7
3	24	181.8	27.8
4	27	140.0	76.8
5	27	171.9	66.1
6	30	169.0	41.7
7	21	144.7	73.7

POOLED ST. DEV. = 56.3

```
INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
1                           I+++++++++++I++++++++++I
2                        I++++++++I++++++++I
3                        I+++++++++I+++++++++I
4       I+++++++++I+++++++++I
5                    I+++++++++I++++++++I
6                   I+++++++++I++++++++I
7        I++++++++++I++++++++++I
       +---------+---------+---------+---------+---------+---------+
     115.      140.      165.      190.      215.      240.      265.
```

--

?

```
ONEW APPEARANCE FOR PINE C16 C11

                                 LEVEL
                  ALL
                  DATA     1      2      3      4

             -     26      7      9      5      5
             -
       200.  +
             -     45      6     13     17      9
             -
             -     16      2      5      2      7
             -
       100.  +
             -
             -
             -
             -      7             1             6

ANALYSIS OF VARIANCE

DUE TO          DF         SS     MS=SS/DF      F-RATIO
FACTOR           3      41006.      13669.         4.90
ERROR           90     251150.       2791.
TOTAL           93     292156.


LEVEL         N           MEAN        ST. DEV.
1            15           196.5          36.4
2            28           180.5          47.7
3            24           181.8          27.8
4            27           140.0          76.8

POOLED ST. DEV. =          52.8

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
1                           I************I*************I
2                      I*********I*********I
3                      I**********I**********I
4      I*********I*********I
       +---------+---------+---------+---------+---------+---------+
     120.      140.      160.      180.      200.      220.      240.

--
```

```
ONEW APPEARANCE FOR SPRUCE-FIR C26 C21

                             LEVEL
              ALL
              DATA     5       6       7

          -     18      9       5       4
          -
    200.  +
          -     36     13      16       7
          -
          -     16      2       8       6
          -
    100.  +
          -
          -
          -
          -      8      3       1       4

 ANALYSIS OF VARIANCE

DUE TO          DF          SS       MS=SS/DF      F-RATIO
FACTOR           2      10213.         5106.         1.40
ERROR           75     272731.         3636.
TOTAL           77     282943.

LEVEL        N           MEAN       ST. DEV.
5           27          171.9          66.1
6           30          169.0          41.7
7           21          144.7          73.7

POOLED ST. DEV. =        60.3

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
       +---------+---------+---------+---------+---------+---------+
5                           I**************I*************I
6                          I*************I*************I
7        I*****************I***************I
       +---------+---------+---------+---------+---------+---------+
     115.      130.      145.      160.      175.      190.      205.

--
?
```

```
ONEW %VOLUMETRIC SHRINKAGE FOR ALL DATA (CLL) C1 C2

                                    LEVEL
                    ALL
                    DATA     1      2      3      4      5      6      7

             -        1                                                1
             -
             -
             -
      16.0   +
             -
             -        5             1      1      1             1      1
             -       32      3      7      6     12      2      2
             -       96      4     12     15     13     21     19     12
       8.0   +       53      6      8      8      5      7      6     13
             -        4      1      1                           1      1
```

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	11.91	1.98	.80
ERROR	184	455.91	2.48	
TOTAL	190	467.82		

LEVEL	N	MEAN	ST. DEV.
1	14	8.94	1.29
2	29	9.39	1.52
3	30	9.54	1.25
4	31	9.92	1.24
5	30	9.34	.86
6	29	9.29	1.24
7	28	9.42	2.81

POOLED ST. DEV. = 1.57

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1        I****************I**************I
2                      I**********I**********I
3                         I**********I**********I
4                                  I*********I***********I
5                     I***********I**********I
6                    I***********I**********I
7                       I**********I***********I
       +---------+---------+---------+---------+---------+---------+
      8.00      8.50      9.00      9.50     10.00     10.50     11.00
```

FREEDOM FROM CHECKS = RECIPROCAL OF THE TOTAL AREA OF THE OPENINGS IN SQUARE INCHES (100 = A PIECE WITH NO CHECKS)

```
ONEW FREEDOM FROM CHECKS FOR ALL DATA C13 C1

ANALYSIS OF VARIANCE

DUE TO          DF          SS      MS=SS/DF      F-RATIO
FACTOR           6     179190.        29865.        14.66
ERROR          422     859594.         2037.
TOTAL          428    1038783.

LEVEL           N         MEAN        ST. DEV.
1              37         73.2          44.6
2              69         56.8          49.6
3              60         37.1          48.3
4              70         88.9          31.3
5              69         38.1          48.5
6              65         34.1          47.5
7              59         73.5          43.8

POOLED ST. DEV. =         45.1

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
        +---------+---------+---------+---------+---------+---------+
1                                     I********I*********I
2                              I*******I******I
3           I******I*******I
4                                                  I******I******I
5            I******I******I
6         I******I*******I
7                                       I*******I******I
        +---------+---------+---------+---------+---------+---------+
       20.       35.       50.       65.       80.       95.      110.
```

FREEDOM FROM WARP = RECIPROCAL OF TOTAL DEFLECTION FROM PLANE MEASURED IN 16 THS OF INCHES (100 = A PERFECTLY STRAIGHT PIECE)

ONEW FREEDOM FROM WARP FOR ALL DATA C12 C1

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	6	.026355	.004392	5.09
ERROR	422	.364319	.000863	
TOTAL	428	.390677		

LEVEL	N	MEAN	ST. DEV.
1	37	.0937	.0376
2	69	.0816	.0278
3	60	.0901	.0310
4	70	.0856	.0290
5	69	.0837	.0263
6	65	.1036	.0269
7	59	.0792	.0302

POOLED ST. DEV. = .0294

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
         +---------+---------+---------+---------+---------+---------+
1                     I*********I**********I
2           I*******I******I
3                   I*******I*******I
4               I*******I*******I
5             I*******I*******I
6                                 I*******I*******I
7        I*******I*******I
         +---------+---------+---------+---------+---------+---------+
       .0780     .0810     .0900     .0990     .1080     .1170     .1260
```

ONEW FREEDOM FROM WARP FOR PINE C22 C11

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	3	.004391	.001464	1.56
ERROR	232	.218176	.000940	
TOTAL	235	.222567		

LEVEL	N	MEAN	ST. DEV.
1	37	.0937	.0376
2	69	.0816	.0278
3	60	.0901	.0310
4	70	.0856	.0290

POOLED ST. DEV. = .0307

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
1                          I***************I***************I
2          I***********I***********I
3                       I************I************I
4                 I***********I***********I
       +---------+---------+---------+---------+---------+---------+
     .0720     .0780     .0840     .0900     .0960     .1020     .1080
```

--
?

ONEW FREEDOM FROM WARP FOR SPRUCE-FIR C32 C21

ANALYSIS OF VARIANCE

DUE TO	DF	SS	MS=SS/DF	F-RATIO
FACTOR	2	.021479	.010740	13.96
ERROR	190	.146143	.000769	
TOTAL	192	.167622		

LEVEL	N	MEAN	ST. DEV.
5	69	.0837	.0263
6	65	.1036	.0269
7	59	.0792	.0302

POOLED ST. DEV. = .0277

INDIVIDUAL 95 PERCENT C. I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)

```
       +---------+---------+---------+---------+---------+---------+
5            I******I******I
6                                  I******I*******I
7      I*******I*******I
       +---------+---------+---------+---------+---------+---------+
     .0720     .0810     .0900     .0990     .1080     .1170     .1260
```

--
?